TRANSACTIONS

OF

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

1918

VOL. XXVI 1918

TRANSACTIONS

MARINE
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OF

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

EDITED BY THE SECRETARY

PRINCIPAL OFFICE OF THE SOCIETY
ENGINEERING SOCIETIES BUILDING
29 WEST 39th STREET, NEW YORK, N. Y., U. S. A.

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OFFICERS OF THE SOCIETY

President.

WASHINGTON L. CAPPS.

Past Presidents and Life Members.

FRANCIS T. BOWLES, STEVENSON TAYLOR.

Past President and Life Associate Member.

ROBERT M. THOMPSON.

Honorary Vice-Presidents.

F. L. FERNALD, D. W. TAYLOR,
F. E. KIRBY, W. M. McFARLAND.

Vice-Presidents.

Term expires December 31, 1919:

A. P. NIBLACK, H. D. GOULDER,
R. M. WATT, C. P. WETHERBEE.

Term expires December 31, 1920:

W. F. DURAND, W. J. BAXTER,
H. L. FERGUSON, H. A. MAGOUN.

Term expires December 31, 1921:

LEWIS NIXON, C. H. PEABODY,
H. I. CONE, J. W. POWELL.

Members of Council.

Term expires December 31, 1919:

J. H. LINNARD, W. L. R. EMMET, H. C. HIGGINS,
C. A. McALLISTER, J. H. GARDNER, SPENCER MILLER.

Term expires December 31, 1920:

H. C. SADLER, D. H. COX, A. C. PESSANO,
F. L. DuBOSQUE, W. A. DOBSON, C. F. BAILEY.

Term expires December 31, 1921:

W. D. FORBES, R. H. M. ROBINSON, J. H. MULL,
A. FLETCHER, W. G. COXE, ROBERT HAIG.

Associate Members of Council.

Term expires December 31, 1919:

R. A. C. SMITH, ALBERT W. GOODRICH.

Term expires December 31, 1920:

H. L. ALDRICH, H. H. RAYMOND.

Term expires December 31, 1921:

E. M. BULL, C. M. WALES.

Executive Committee.

WASHINGTON L. CAPPS, *Ex-Officio.*

STEVENSON TAYLOR, W. M. McFARLAND, J. W. POWELL,
ANDREW FLETCHER, F. L. DuBOSQUE, D. H. COX, *Ex-Officio.*

Secretary-Treasurer.

DANIEL H. COX.

ARTICLES OF INCORPORATION

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

State of New York,
City and County of New York.

We, the subscribers, Wm. H. Webb, Chas. H. Cramp, George E. Weed, H. Taylor Gause, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, Edwin D. Morgan, George W. Quintard, Harrington Putnam and Jacob W. Miller, being persons of full age and citizens of the United States, of whom a majority—namely, William H. Webb, George E. Weed, Horace See, Edwin D. Morgan, George W. Quintard, Harrington Putnam, Frank L. Fernald, and Jacob W. Miller are citizens of and residents of and within this State, desiring to associate ourselves for scientific purposes under, and pursuant to, an Act of the State of New York providing for the incorporation of benevolent, charitable, scientific, and missionary societies, passed April 12, 1848, and the several acts amending or supplementing the same, do hereby, in accordance with the requirements thereof, certify as follows:—

First. The name of title by which the Society shall be known in law is The Society of Naval Architects and Marine Engineers.

Second. The particular business and objects of such Society are the promotion of practical and scientific knowledge in the arts of shipbuilding and marine engineering and the allied professions, and in furtherance of this object, to hold meetings for social intercourse among its members, and the reading and discussion of professional papers, and to circulate by means of publication the knowledge thus obtained.

Third. The number of directors, trustees, or managers to manage the Society shall be seven, and shall consist of a President, a Secretary, and five Members of Council.

Fourth. The names of the trustees, directors, or managers of the Society for the first year of its existence are:—President, Clement A. Griscom; Secretary, Washington L. Capps; Members of Council, Francis T. Bowles, H. Taylor Gause, Chas. H. Loring, Lewis Nixon, Harrington Putnam.

Fifth. The business of the Society is to be conducted, and its place of business and principal office is to be located, in the City and County of New York.

In Witness Whereof we have made, signed, and acknowledged this Certificate, this 28th day of April, 1893.

WILLIAM H. WEBB.
CHAS. H. CRAMP.
H. T. GAUSE.
GEORGE E. WEED.
W. T. SAMPSON.
HORACE SEE.
F. L. FERNALD.
FRANCIS T. BOWLES.
W. L. CAPPS.
E. D. MORGAN.
GEORGE W. QUINTARD.
HARRINGTON PUTNAM.
J. W. MILLER.

City and County of New York, *ss:*

On this 28th day of April, 1893, before me personally appeared William H. Webb, Charles H. Cramp, H. Taylor Gause, George E. Weed, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, and Edwin D. Morgan, to me known and known to me to be the persons described in and who executed the foregoing certificate, and severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss:*

On this 1st day of May, 1893, before me personally appeared George W. Quintard and Harrington Putnam, to me known and known to me to be the individuals described in and who executed the foregoing certificate, and they severally acknowledged to me that they executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

City and County of New York, *ss:*

On this 9th day of May, 1893, before me personally appeared Jacob W. Miller, to me known and known to me to be one of the individuals described in and who executed the foregoing certificate, and he duly acknowledged to me that he executed the same.

James Forrester,
Notary Public, Kings Co., Cert. N. Y. Co.

(Endorsed.)

Upon reading the within Certificate for the Incorporation of the Society of Naval Architects and Marine Engineers, I hereby approve and consent to the incorporation thereof and the within Certificate and filing thereof, and direct that the same be filed in the office of the Clerk of the City and County of New York.

Dated New York, May 10, 1893.

Edwd. Patterson,
Justice of the Supreme Court in the State of New York
in and for the City and County of New York.

INTRODUCTORY PROCEEDINGS

MINUTES OF THE TWENTY-SIXTH ANNUAL MEETING OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, HELD AT WITHERSPOON HALL, PHILADELPHIA, PA., THURSDAY AND FRIDAY, NOVEMBER 14 AND 15, 1918.

FIRST SESSION.

THURSDAY MORNING, NOVEMBER 14, 1918.

The President, Mr. Stevenson Taylor, called the meeting to order at 9.55 a.m., and said:—"Gentlemen, I now call to order the Twenty-sixth Annual Meeting of the Society of Naval Architects and Marine Engineers. The first business in order is the reading of the annual report by the Secretary-Treasurer, Mr. Daniel H. Cox. I presume he will read that in brief."

Mr. Cox presented the following report:—

REPORT OF SECRETARY-TREASURER.

NOVEMBER 13, 1918.

To the Council of The Society of Naval Architects and Marine Engineers:—

GENTLEMEN:—I have the honor to submit the following report showing the condition of the Society at the close of the fiscal year ended October 31, 1918.

The membership of the Society November 1, 1918, was as follows:—

Class of Members.	Membership November 1, 1917.	Elected at 1917 Meeting.	Promotion, Associate to Member.	Promotion, Junior to Member.	Promotion, Junior to Associate.	Reinstated.	Suspended by Council.	Membership at close Annual Meeting, 1917.	Deaths, 1917-1918.	Resignations, 1917-1918.	Membership, November 1, 1918.
Members	640	90	+3	+2	—	2	11	726	8	9	709
Associates	190	27	—3	—	+1	1	5	211	4	5	202
Juniors	29	11	—	—2	—1	—	—	37	—	—	37
Life Members	5	—	—	—	—	—	—	5	1	—	4
Life Associates	5	1	—	—	—	—	—	6	—	—	6
Honorary Members	1	—	—	—	—	—	—	1	—	—	1
Honorary Associates	2	—	—	—	—	—	—	2	1	—	1
Totals	872	129	—	—	—	3	16	988	14	14	960

RECEIPTS.

From November 1, 1917, to October 31, 1918, inclusive.

Entrance fees of new members for the year ending December 31, 1918:—		
Members	$860 00	
Associates	240 00	
Juniors	50 00	
		$1,150 00
Entrance fee of new member for the year ended December 31, 1917:—		
Associate		10 00
Dues for the year ending December 31, 1918:—		
Members	$6,090 00	
Associates	1,760 00	
Juniors	135 00	
		7,985 00
Dues for the year ended December 31, 1917:—		
Members	$545 00	
Associates	260 00	
Juniors	10 00	
		815 00
Dues for the year ended December 31, 1916:—		
Members	$120 00	
Associates	50 00	
Juniors	5 00	
		175 00
Dues for the year ended December 31, 1915:—		
Members	$80 00	
Associates	10 00	
		90 00
Dues for the year ended December 31, 1914:—		
Members	$30 00	
Associates	10 00	
		40 00
Dues for the year ended December 31, 1913:—		
Member		10 00
Entrance fees and dues paid in advance:—		
Entrance fees for November, 1918, meeting	$175 00	
Life associate member	200 00	
Transfer junior to member	5 00	
Advance dues	205 00	
		585 00
Dues in arrears, reinstated member		40 00
Total fees and dues collected		$10,900 00
Sales of Publications:—		
Society transactions to members and dealers	$1,096 00	
Special editions of papers	180 50	
		1,276 50
Exchange on remittances, members' dues		4 90
Banquet, annual meeting, 1917		2,870 40
Subscriptions for expenses, annual meeting and banquet, 1918		2,400 00
Banquet, annual meeting, 1918, reservations		495 00
Sale of office material		5 00
Junior prize donation, H. L. Aldrich		100 00
Proceeds of Liberty Bonds sold for reinvestment later i sue		1,004 64
Interest:—From investments	$1,087 40	
From bank balances	32 10	
		1,119 50
Total receipts		$20,175 94
Balance, cash in bank and on hand, November 1, 1917		1,481 60
		$21,657 54

STATEMENT.

DISBURSEMENTS.

From November 1, 1917, to October 31, 1918, inclusive.

Publications:—		
Printing Volume 25	$5,958 04	
Membership year book	250 40	
Forwarding volumes and papers	45 38	
Storage of volumes	185 35	
		$6,439 17
Rent of safe deposit box, Franklin Trust Company		5 00
Expenses, 25th Annual Banquet, November, 1917		2,643 55
Expenses, 25th Annual Meeting, November, 1917		758 25
Expenses, 26th Annual Meeting, November, 1918		149 35
Exchange on remittances, members' dues		8 61
Salaries and clerical expenses		2,029 88
Audit of books and accounts to November 1, 1917		190 00
Rent of society rooms		294 00
Office expenses, postage, stationery, etc		1,184 39
Accrued interest on Liberty Bonds purchased		31 87
Investment:—		
Purchase of Liberty Bonds		2,970 00
Total disbursements		$16,704 07
Balance cash, October 31, 1918:—		
In Franklin Trust Company	$4,910 53	
On hand	42 94	
		4,953 47
		$21,657 54

DEATHS (14).

Honorary Associate (1).

Rt. Hon. Lord Brassey, K.C.B.

Life Member (1).

Edwin A. Stevens.

Members (8).

George W. Dickie.
Charles R. Hanscom.
Robert Logan.
George W. Magee.
Ignatius E. Thayer.
William H. Varney.
John D. Van Buren.
John F. Wentworth.

Associates (4).

Harry B. Bloomsburg.
Frank S. Masten.
Thomas S. Matthewson.
Jacob W. Miller.

RESIGNATIONS (14).

Members (9).

George F. Adams.
Lee S. Border.
Harry L. Brinser.
Thomas S. Hall.
Harry W. Hand.
Charles H. Manning.
James S. Morton.
Alfred H Raynal.
William E. Reynolds.

Associates (5)

E. F. Eggert.
John M. Emery.
James A. Guthrie, Jr.
Anton A. Raven.
William H. Ripley.

The following delinquencies exist in the payment of dues:—

For the year ended December 31, 1914:—		
Members	$20 00	
Associates	10 00	
		$30 00
For the year ended December 31, 1915:—		
Members	$130 00	
Associates	40 00	
		170 00
For the year ended December 31, 1916:—		
Members	$200 00	
Associates	60 00	
Juniors	5 00	
		265 00
For the year ended December 31, 1917:—		
Members	$370 00	
Associates	85 00	
Juniors	20 00	
		475 00
For the year ended December 31, 1918:—		
Members	$1,160 00	
Associates	380 00	
Juniors	55 00	
		1,595 00
Total outstanding dues at October 31, 1918		$2,535 00

Statement of Resources and Liabilities.

RESOURCES.

Membership dues		$2,525 00	
Deductions:—			
Deaths	$40 00		
Resignations	200 00		
Doubtful accounts	200 00		
		440 00	
			$2,085 00
Dues from dealers and individuals for volumes			748 00
Office furniture and equipment at 30 per cent of cost			885 00
Publications on hand:—			
Previous to volume No. 18 at 50 per cent of cost; Volumes Nos. 19 to 25, inclusive, at cost			6,744 37
Investments:—			
Municipal Bonds, City of New York, at par		$12,000 00	
4 Baltimore and Ohio R. R. Bonds, 1933 convertible, at cost		3,925 00	
3 Central Pacific Railway Co. Bonds, 1949, 1st refunding, at cost		2,651 25	
2 Morris and Essex Bonds, 2,000 refunding, at cost		1,732 50	
Liberty Loan Bonds		2,990 00	
			23,298 75
Cash on deposit, Franklin Trust Company		$4,910 53	
Cash on hand		42 94	
			4,953 47
Total resources			$38,714 59

LIABILITIES.

Annual banquet, 1918, paid in advance	$460 00
Subscriptions for expenses 1918 annual meeting	2,400 00
Members' fees and dues paid in advance	390 00
Volumes paid for and and not delivered owing to transportation embargo	197 21
Junior prize donations, H. L. Aldrich, Member of Council	100 00
Total liabilities	$3,547 21
Society's present worth at October 31, 1918*	35,167 38
	$38,714 59

*By the provisions of the Endowment Fund, adopted in 1914, the division of the Society's present worth at October 31, 1918, is as follows:—

Balance at November 1, 1917		$15,950 00
Additions, 1917-1918:—		
Membership entrance fees	$1,540 00	
Investment income, municipal bonds	490 00	
		2,030 00
Balance at October 31, 1918, Endowment Fund		$17,980 00
Net assets other than Endowment Fund		17,187 38
		$35,167 38

The financial statements have been verified by Webster & Mills, Certified Public Accountants of New York.

Respectfully submitted,

DANIEL H. COX,
Secretary-Treasurer.

Secretary Cox:—Mr. President and gentlemen, the report has been distributed to all the membership, and I will just touch on the essentials. With respect to the membership, a statement is shown on the first page. On coming to this meeting we have a membership of 960. A year ago, at the same time, the membership was 872. At the last annual meeting there were elected 129, but this was reduced owing to deaths, resignations and suspensions. The Society will be interested to know that there have already been received and favorably passed on by the Committee on Membership and by the Council 440 new members for election this year, so that if we did very well last year in getting 95 new members, and as our total membership now is less than 1,000, we are to be congratulated on having secured at least 440 new members this year. I think, as a matter of fact, the number of applications for membership will probably go over 500, as there are a large number of applications on their way to us.

The statement of receipts and disbursements is interesting. The essentials are that we have purchased during the year $3,000 of Liberty Bonds which are added to our assets, and we also have $1,000 more cash balance than last year; as all bills have been paid, our actual present worth is increased over last year by $4,000.

The Secretary then read the list of deaths of members which had occurred during the past year.

The President:—The members will please rise *in memoriam.*

Many of these names, gentlemen, appeal to me personally, because I have known most of these men for a great many years. I wish to take the opportunity of referring to three or four.

The Rt. Hon. Lord Brassey—Those of you who have had the pleasure of meeting Lord Brassey will remember his strong, virile character and his great accomplishments. I shall never forget, in 1911, when he presided at a meeting, he suddenly called upon me to make an address. I had not the slightest notion of making any address, but his manner seemed to command me at once, and I naturally acceded, and, I may say, with pleasure.

Col. Edwin A. Stevens—I have been associated with Col. Stevens in many things for a great many years past. He gave his life to his country, because he was overcome by illness, an outcome of his labors. He was taken ill with pneumonia, and died as truly for his country as a man in the trenches.

Mr. George W. Dickie—Mr. Dickie was a fine, manly figure from San Francisco. You will all remember that he read a number of papers before this Society. They were of much value, and he was always interesting in discussion. He wrote a letter in August last, saying that he expected to be here, and complimented the Secretary on the subjects of the papers to be read. He died within a few days after writing that letter.

Mr. George W. Magee—One of the oldest members in the Society by age. He was an assistant of the Engineer-in-Chief of the United States Navy in the early Civil War years. He was a genial gentlemen, highly esteemed by all who knew him.

Commodore Jacob W. Miller—Commodore Miller, as you well know, was very prominent at all of our meetings, taking part in papers and discussions, and always adding to the interest of the occasion, whether meeting or banquet.

Referring to the last three mentioned, Colonel Stevens, Mr. Dickie and Commodore

Miller, it is fitting to say that the Council has passed resolutions setting forth, more fully than I need do here, the history, worth and service of these gentlemen. These resolutions will be published in the transactions and an engrossed copy sent to their respective families.

So our friends and fellow-members pass on from year to year, and we hold in reverence their memories.

THE SECRETARY:—The next subject dealt with in the Secretary-Treasurer's report is that of dues not paid up, and in that matter we are also better off than usual. We have $500 less outstanding dues this year than last year.

The last sheet gives an itemized statement of resources and liabilities, and the most interesting feature of that is the statement at the bottom with respect to the Endowment Fund. That fund, as you will see, is now within $20 of $18,000, being $17,980, which is a very large addition to the sum we had when we commenced.

THE PRESIDENT:—It is my pleasure to announce to you, gentlemen, that yesterday afternoon at the meeting of the Council there was nominated as president of this Society, to succeed the present incumbent on January 1, 1919, Rear Admiral Washington Lee Capps. (Applause.) May I assume from your fine and enthusiastic applause that we can call him president-elect by acclamation? I shall so do. I congratulate the Society on the election of Admiral Capps.

The Council also elected as Honorary Vice-Presidents, Rear Admiral D. W. Taylor and Mr. W. M. McFarland.

For Vice-Presidents, for the term expiring December 31, 1921:—Lewis Nixon, H. J. Cone, C. H. Peabody, and J. W. Powell.

H. D. Goulder, *vice* Commodore J. W. Miller, deceased, for the term expiring December 31, 1919.

W. J. Baxter, *vice* W. L. Capps, for the term expiring December 31, 1920.

H. A. Magoun, *vice* D. W. Taylor, for the term expiring December 31, 1920.

C. P. Wetherbee, *vice* W. M. McFarland, for the term expiring December 31, 1919.

For Members of Council, for the term expiring December 31, 1921:—W. G. Coxe, A. Fletcher, W. D. Forbes, *vice* W. J. Baxter; Robert Haig, *vice* H. A. Magoun; J. H. Mull, and R. H. M. Robinson.

For Member of Council, for the term expiring December 31, 1919:—Spencer Miller, *vice* C. P. Wetherbee.

For Member of Council, for the term expiring December 31, 1920:—C. F. Bailey, *vice* J. W. Powell.

For Associate Members of Council, for the term expiring December 31, 1921:—E. M. Bull, and C. M. Wales, *vice* H. D. Goulder.

As Executive Committee:—Messrs. Stevenson Taylor, Andrew Fletcher, W. M. McFarland, F. L. DuBosque, and J. W. Powell.

As the Committee on Papers:—Messrs. W. M. McFarland, F. L. DuBosque, and H. L. Aldrich.

Last, but by no means least, Secretary-Treasurer, Mr. Daniel H. Cox.

I hope that all of these elections meet with your approval.

The Secretary has announced to you that there are 440 applications for membership, which have been passed upon by the Committee on Membership and the Council, and there

will probably be 500 before long, but to save time I will take the liberty of not having these names read, assuming that you will be satisfied with the judgment of the Committee on Membership and the Council. Those of you who are in favor of this procedure will say "Aye"; contrary-minded, "No." It is unanimously carried, and the names as passed by the Council will be entered upon our list of membership in the respective grades.

Members (308).

Thomas H. Addie, American Manganese Bronze Co., Harrisburg, Pa.
Frederick W. Allan, 20 Dorchester Road, Buffalo, N. Y.
Jean H. Allen, 5006 Dorchester Avenue, Chicago, Ill.
Thomas J. Allan, 578 Orange Avenue, Long Beach, Cal.
Clement G. Amory, Gas Engine & Power Co., and Charles L. Seabury & Co., Morris Heights, N. Y.
Arthur G. Anderson, 405 First Street., San Pedro, Cal.
Walter E. Anderson, 1822 9th Street, Alameda, Cal.
James D. Andrew, The Lenox, 13th and Spruce Streets, Philadelphia, Pa.
Henry E. Ankener, Terry Shipbuilding Corporation, Savannah, Ga.
George A. Armes, 1155 Greenwich Street, San Francisco, Cal.
David Arnott, 104 Hillside Avenue, Orange, N. J.
William G. Atherholt, 415 Victoria Place, Toledo, Ohio.
Herman G. Babcock, 938 16th Avenue, N. Seattle, Wash.
John C. Baine, 1144 E. 18th Street, Brooklyn, N. Y.
James F. Barber, 6721 N. Sydenham Street, Philadelphia, Pa.
Howel H. Barnes, Jr., General Electric Co., 120 Broadway, New York, N. Y.
Joseph A. Barton, Lieut., C. C., U. S. N.,199 Van Buren Street, Brooklyn, N. Y..
Ivan E. Bass, Commander, U. S. N., Navy Yard, Boston, Mass.
Walter R. Bean, 124 N. Davis Street, Woodbury, N. J.
Walt B. Beebe, 206 11th Avenue, N. Seattle, Wash.
Walter J. Belsey, 91 Wellington St., Glasgow, Scotland.
William Bennett, Lloyd's Register of Shipping, 17 Battery Place, New York, N. Y.
Charles E. Betts, 1538 Harlem Avenue, Baltimore, Md.
John F. Blain, U. S. Shipping Board, Securities Building, Seattle, Wash.
David Blair, 2129 W. 93rd Street, Cleveland, Ohio.
George L. Blatz, Jr., 437 Oak Street, Audubon, N. J.
Ernest W. Blockridge, 507 Orange Street, Wilmington, N. C.
Alfred V. Bouillon, C. E., Empire Building, Seattle, Wash.
William Boyd, P. O. Box 269, New London, Conn.
Hugh Boyle, 425 King Street, Jacksonville, Fla.
Ralph W. Bragg, 64 Pearl Street, Bath, Maine.
Alexander de Bretteville, 163 Main Street, San Francisco, Cal.
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Donald D. Smith, c/o Merchants Shipbuilding Corpn., Harriman, Pa.
P. L. Smith, 1309 King Street, Wilmington, Del.
William H. Smith, 109 Maple Street, Brooklyn, N. Y.
William M. Stanton, Lansdowne, Pa.
Kenneth Stephens, 5205 Archer Street, Germantown, Pa.
C. L. Thompson, P. O. Box 623, Bremerton, Wash.
John Thomson, 704 Washington Street, Bath, Maine.
John E. Tonnelier, 304 Price Avenue, Narberth, Pa.
John N. Trainer, 366 5th Avenue, New York, N. Y.
Philip S. Tyre, 6505 Fairhill Street, Oak Lane, Philadelphia, Pa.
S. A. Vincent, G. H. Standifer Const. Corpn., Vancouver, Wash.
Carl G. Vretman, Stonington, Conn.
Robert B. Wallace, c/o Virginia Shipbuilding Corpn., Alexandria, Va.
Albert R. Ware, 1517 Wildwood Avenue, Camden, N. J.
C. W. Watson, c/o Saginaw S. S. Co., Saginaw, Mich.
George H. Weir, So. Bellingham, Wash.
Morris Wenk, 801 West 10th Street, Vancouver, Wash.
Richard O. White, Groton Iron Works, Groton, Conn.

R. W. Williams, 5404 Chester Avenue, Philadelphia, Pa.
Edward E. Winters, 15 Broad Street, New York, N. Y.
William S. Wolfe, Box 65, North Glenside, Montgomery County, Pa.
Norman A. Yarrow, P. O. Box 1595, Victoria, B. C.
Charles E. Zollars, Drexel Hill, Pa.

Juniors (33).

E. E. Aldrich, 9 Charlotte Street, Worcester, Mass.
E. H. Alsop, 3735 Walnut Street, West Philadelphia, Pa.
Bruce T. Bair, 2309 S. 15th Street, Philadelphia, Pa.
A. E. Boyle, 155 Lowell Street, San Francisco, Cal.
Wm. G. Brown, 275 Newbury Street, Boston, Mass.
H. L. Carroll, Box 174, Vancouver, Wash.
James G. Craig, c/o Long Beach Shipbuilding Co., Long Beach, Cal.
Irving Fineman, Cramp's Shipyard, Philadelphia, Pa.
Kenneth Fisk, 37 Madison Avenue, New York, N. Y.
F. G. Healy, 36 Kingsville Avenue, Ashtabula, Ohio.
Anton Kaufmann, 513 Cornelia Street, Saginaw, Mich.
Robert B. Lea, c/o Sperry Gyroscope Co., Manhattan Bridge Plaza, Brooklyn, N. Y.
N. G. Leemon, 154 Adelphia Street, Brooklyn, N. Y.
M. M. Leffer, U. S. S. Maine, c/o Postmaster, Fortress Monroe.
H. C. Lenfest, c/o Fabricated Ship Corpn., Milwaukee, Wis.
Frank M. Lewis, 24 E. Stewart Avenue, Lansdowne, Pa.
H. L. Lilla, U. S. S. Bridgeport, c/o Postmaster, New York, N. Y.
Ian L. McKenzie, 409 Markham Street, Toronto, Can.
W. C. Mehaffey, U. S. Naval Station, New Orleans, La.
George V. Mulligan, 714 West 13th Street, Vancouver, Wash.
Edward M. Murphy, 1629 N. 15th Street, Philadelphia, Pa.
William Nelson, Lieut., C. C., U. S. N., Navy Yard, Philadelphia, Pa.
F. J. Nicosia, 108 S. 5th Street, Wilmington, N. C.
A. A. Norton, 1923 Harney Street, Vancouver, Wash.
Joseph F. Novachek, Grays Harbor Motorship Corpn., Aberdeen, Wash.
E. C. Rechtin, 129 Clifton Place, Jersey City, N. J.
H. F. Robinson, 11857 Clifton Boulevard, Cleveland, Ohio.
M. J. Ryan, 606 19th Street, San Francisco, Cal.
C. B. Shovar, No. 3, 87th Avenue, W. Duluth, Minn.
H. C. Snethlage, c/o Chas. T. Stork & Co., Inc., Tribune Building, New York, N. Y.
Thomas H. Soyster, 1923 Harney St., Vancouver, Wash.
H. H. Tremble, 219 E. 12th Street, Oakland, Cal.
E. P. Warner, Massachusetts Institute of Technology, Cambridge, Mass.

From Associates to Members (8).

John W. Anderson, Electric Boat Co., Groton, Conn.
Carlos de Zafra, 353 West 57th Street, New York, N. Y.
Harry B. Etter, 2322 N. 17th Street, Philadelphia, Pa.

Wentworth W. Meek, 27 Groton Street, New London, Conn.
Edmond R. Norton, c/o Lake Torpedo Boat Co., Bridgeport, Conn.
Robert A. Sheerin, A. P. O. No. 760, American Expeditionary Force, France.
S. Peirce Taylor, 123 West 85th Street, New York, N. Y.
John Winslow, 20 Cleveland Street, New Brighton, Staten Island, N. Y.

From Juniors to Members (3).

George A. Andrews, Lieutenant, C. C., U. S. N., Navy Yard, Boston, Mass.
Louis A. Baier, 2601 Allendale Road, Baltimore, Md.
Caryl H. Roundy, 36 Summer Street, Port Chester, N. Y.

From Juniors to Associates (5).

Charles F. Gross, 916 East North Avenue, Baltimore, Md.
Richard D. Karr, 81 Van Houten Avenue, Passaic, N. J.
Carl J. Nordstrom, Hotel Mallory, Portland, Ore.
Henry J. Roundy, 36 Summer Street, Port Chester, N. Y.
Ralph M. Smith, Multnomah Hotel, Portland, Ore.

The President:—The next order of business calls for the reading of the president's annual address.

President Taylor then read his annual address, which was followed with much interest and greeted with applause.

PRESIDENT'S ADDRESS.

On July 26, 1892, after the launching of the U. S. S. Columbia at the Cramp Shipyard, Naval Constructor David W. Taylor entertained his colleagues at the University Club in Philadelphia. There were present Naval Constructor Francis T. Bowles, Naval Constructor Washington L. Capps, Naval Constructor Ruhm (now deceased), and Naval Constructor Lewis Nixon, who had recently resigned from the service and at this time occupied a very responsible position with the William Cramp & Sons Company. The founding of a society on the lines of the British Institution of Naval Architects was brought up by Naval Constructor (now Admiral) Bowles, and heartily approved by all.

Naval Constructor (now Admiral) Capps was requested to act as provisional secretary and to prepare letters to be sent to shipbuilders, marine engineers, naval officers and others professionally interested.

This in due course was done and on the 28th day of April, 1893, there were duly signed and acknowledged the Articles of Incorporation of The Society of Naval Architects and Marine Engineers under the laws of the State of New York; and on November 16 of the same year the first general meeting of the Society was held in the Auditorium of the American Society of Mechanical Engineers, then situated at 12 West 31st Street, New York City.

This Society therefore now at its twenty-sixth meeting celebrates the twenty-fifth anniversary of its incorporation and its first meeting.

It is particularly interesting to note who were the incorporators, what was done at the first meeting, and the general conditions then existing.

The first president was Clement A. Griscom, and to Lewis Nixon we owe his nomination. In memory of Mr. Griscom be it said that for ten successive years he was elected

to this high office and satisfactorily performed its duties. I can do no better than to quote from his first presidential address:—"The organization of this Society at this time, under the inspiration of such names as William H. Webb, Charles H. Cramp, George E. Weed, H. Taylor Gause, William T. Sampson, Horace See, Frank L. Fernald, Francis T. Bowles, Washington L. Capps, Edwin D. Morgan, George W. Quintard, Harrington Putnam, and Jacob W. Miller is significant of the lively interest which the busy people of this country are at last taking in the international struggles for marine supremacy"; and speaking of his own election, President Griscom said:—"While I am grateful for this distinction, I do not accept the honor as a personal tribute, but rather as your recognition of the important interests over which I preside, and which are so intimately connected with your art." No one who knew Clement A. Griscom will ever forget his ability or his charm which so well deserved the personal tribute he modestly denied, nor the importance of his advocacy of an American merchant marine.

What recollections the names of the incorporators bring to our minds:—

William H. Webb, one of the foremost shipbuilders of the United States, whose achievements in wood clipper ships and ships of war for this and other nations are too numerous to mention, and whose memory and patriotism are kept sacred by his endowment of Webb's Academy and Home for Shipbuilders, an institution unique in the world, where young men are taught the science and art of naval architecture and marine engineering and are also provided with board and lodging entirely free of cost to themselves; and where also certain old shipwrights and engine builders find a free home when age comes upon them and they can no longer work for their daily bread.

Charles H. Cramp, one of the sons of William Cramp, who founded the William Cramp & Sons Company. For many years he was the leading spirit of that great shipbuilding plant, the history of which is so familiar to you.

George E. Weed, that quiet, genial man of high character who for so many years assisted John Roach in financially guiding the Roach yards in Chester and New York.

H. Taylor Gause, who succeeded his father, John Taylor Gause, as the head of the old Harlan and Hollingsworth Company.

William T. Sampson, who bore with his name upon the list of our associate members of those days the simple but powerful letters U. S. N., and who in but five years after our incorporation became Admiral Sampson. U. S. N., and took such a conspicuous part in the events of the Spanish-American War.

Horace See, who, after many years' service with the Cramp Company, became one of the then small number of consulting naval architects, and who was responsible for the design and construction of so many steamships.

George W. Quintard, who founded the Morgan Iron Works (afterward sold to John Roach) and the Quintard Iron Works in New York City; builder of ships and operator as well. Fortunate the man who can recall his personality and friendship.

Jacob W. Miller, a distinguished naval officer and teacher; president of the Providence and Stonington Steamship Company; president of the New England Steamship Company; Commodore of the Naval Militia of the State of New York, and vice-president and general manager of the Cape Cod Canal Construction Company.

These eight of the thirteen incorporators and Clement A. Griscom, the first president of this Society, have all died, leaving records of great achievements deserving our remembrance.

The living incorporators still remain members of our Society:—

Washington L. Capps, the first secretary-treasurer during the years 1893, 1894, and 1895, and again in 1901, 1902, and 1903.

Francis T. Bowles, the first chairman of the Executive Committee and secretary-treasurer during the years 1896 to 1903, inclusive, and president for the six years 1904 and 1909, inclusive.

Frank L. Fernald, the nestor of the United States Navy Construction Corps; vice-president from 1896 to 1912, when he was elected as honorary vice-president, which office he still honors.

Edwin D. Morgan, grandson of New York's Civil War Governor. Enthusiastic in the development of yachts, and particularly along our lines, distinguished by his activities in constructing, managing and sailing several of the great yachts that have from time to time won the races wherein attempts were made to take from our nation the celebrated Queen's Cup won by the America.

Harrington Putnam, well known counsellor-at-law, with a predilection for admiralty matters; member of our Council from 1893 to 1908; now a justice of the Supreme Court of the State of New York.

The services of these men not only to our Society, but to the nation, need no encomiums from me, for you all know how valuable they have been, and you know as well the constant, loyal interest they have borne for so many years and still bear in all matters pertaining to the Society they helped to form twenty-five years ago.

The tenor of most of the papers presented at the first meeting referred to the American merchant marine, and it is evident from the names and connections of the 262 Members, the 155 Associates, and the 3 Juniors of that first year, that the Society was formed with the idea that "the knowledge disseminated by the deliberations and discussions" would add to the development of the commercial as well as the naval power of the United States.

Again quoting President Griscom's opening address, "There can be no doubt that such a society, firmly established by your distinguished membership, should exercise a valuable influence on the future of our navy and of our commercial marine. Sir Nathaniel Barnaby, late Chief Constructor of the British Navy and one of the organizers of the British Institution of Naval Architects, remarked in my presence that no nation could maintain an efficient navy without a prosperous commercial marine to support it."

President Griscom called this a truism, and the statement is a truism to-day as it was twenty-five years ago, and that the United States have succeeded in the past twenty-five years in establishing a navy of which we are proud, and have not until within the last year and a half attempted seriously to establish a commercial marine at all worthy of the country's greatness only proves that there are exceptions even to truisms.

World-wide disturbances caused by the greatest of all wars have now forced in every one of the United States a public opinion that freely gives billions of dollars for an American merchant marine to advance which heretofore an expenditure of anything but a comparative pittance was denied.

Perhaps I am devoting too much time to the event of which we are to-day celebrating, the twenty-fifth anniversary, but reading over the first volume of our Transactions brings to mind the changes that twenty-five years make. A quarter of a century—a generation—naturally makes a great change in the personnel of any association, and a second like period in the future will make a still greater difference. This much, however, is to be said—whether the members of twenty-five years ago accomplished the height of their ambition or

not, they certainly founded, for the membership of to-day and hereafter, a splendid heritage worthy of emulation, a heritage for which present conditions promise with proper care a great and glorious increase.

THE WORLD'S SHIPPING TONNAGE.

The entire merchant tonnage of the world in 1916 did not exceed 50 million gross tons. Of this there has certainly been destroyed by submarines and casualties not less than 14 million gross tons, leaving of the original quantity not over 36 million gross tons. During 1917 and 1918 there will have been built at most 5 million gross tons, making a total of available tonnage only 41 million gross tons. Following the normal increase per annum there should be available at the beginning of 1919 at least 55 million gross tons. From this statement it appears that there will be at the close of the year 1918, a deficit of at least 14 million gross tons, without taking note of the depreciation and repairs which the excessive hard usage of ships during the war will have made necessary.

It is not intended that these figures shall be considered exact, but they are sufficiently so to demonstrate the great necessity still existing for ships; and further to show that our own shipyards must still be urged to their utmost capacity in order that the now important American merchant marine shall be upheld in the future.

AMERICAN SHIPYARD PRODUCTION.

In the year ending June 30, 1908, the entire production of our shipyards was 614,000 gross tons, the greatest previous to 1915; but in the year ending June 30, 1915, the production fell to 225,000 gross tons, the smallest output in seventeen years. In 1916 there came an enormous demand for ships not only from our own citizens, but from foreigners as well.

When the United States entered the war in April, 1917, it became apparent that there was hardly a more important element for winning the war than ships, and the United States Government, through the agencies of its Shipping Board and Emergency Fleet Corporation, immediately proceeded to encourage the building of many new yards as well as the enlarging of the old yards, with the result that there are now about 200 shipyards instead of 66 as in November, 1916. During 1917 there was an output of 800,000 gross tons and the output for 1918 will apparently be about two and one-half million gross tons actually delivered and officially numbered. The increase in our registered shipping during the fiscal year ending June 30, 1918, was 1,053,481 gross tons, more than double that of any previous year and something over the total increases for the first three years of the war combined. At the end of this year there will be over ten million gross tons of shipping under the American flag, or nearly double the amount of three years ago.

NEW METHODS.

The demands upon our facilities for furnishing the usual materials for ships and the lack of men capable of building ships in the usual manner, combined with the extraordinary need of ships, and more ships, to carry on the war, have led to experimenting in building large vessels of other than the usual wood and steel materials.

The successful use abroad of moderate sized boats built of concrete reinforced with steel has led us to go much further, resulting in the building of the Faith, a concrete ship of about

3,000 gross tons, and the placing by the Emergency Fleet Corporation of contracts for 42 concrete ships totaling about 200,000 gross tons.

The details, advantages and disadvantages of building reinforced concrete ships have received a great deal of attention from the officials of the Emergency Fleet Corporation, and it is fair to presume that their investigation has warranted the contracting for four ships of this class of about 2,500 gross tons and 38 ships of about 5,000 gross tons each.

This same question has been also under examination and discussion in Great Britain, and naturally personal designs and views differ materially. Having had no experience in concrete construction and noting the different proportions of steel in several designs and acknowledged contrasts in carrying capacity and speed with like power, I feel that the concrete sea-going ship is still an experiment and that it is quite possible that the emergency which promotes the building of these ships will have vanished before those contracted for will have performed much service. I note with pleasure that there will be presented at this meeting a paper from an authority on the subject, one who has carefully studied the whole subject technically and practically.

Another innovation even more novel than the concrete ship is the proposed electrically welded ship which has now been under consideration for several months. There has been a vessel (perhaps more than one) manufactured on this plan in Great Britain, but the barge is so small that nothing is proved so far as the building of ocean-going ships is concerned. Electric welding certainly has proved successful in many places and under peculiar conditions, so that the proposed construction of a full-size section of a large cargo steamer for complete tests of the method is both interesting and satisfactory. There is also a paper by an authority on this subject which will be especially interesting.

The fabricated cargo ship and the shipyards for building same will also receive at this meeting well-deserved notice, for nowhere has the broad vision of men along these lines been exercised more than in our own country.

RECORDS.

Records of various processes have from time to time been noted. The number of frames erected in a day, the number of rivets driven; the few days that have elapsed between the laying of the keel and the launching and again between the launching and the trial trip; the lineal amount of caulking both on wood and steel ships, and so on to absurdity. We venture to say that in every instance of these special records there has been special preparation that the records shall be made. The fact remains that the general results attained in the long run are not in accordance with the records, and it were better to remember that 400 rivets for every gang for a day's work is a more satisfactory performance than an occasional 1,000 or more rivets.

It must, however, be said in justice that the performance of finishing a ship in an unusually short time and the performance repeated over and over, as has been done, is worthy of the highest commendation.

THE FUTURE.

I have said nothing about the navy, for it is evident from the statements published from time to time that the interests and upbuilding of the navy have not only been well taken care of in the recent years of the great war, but that they will also be as well advanced in the future.

It is to the American merchant marine that we must particularly attend. The shipyards in which our naval vessels have in the past been built will also build what will be required for the navy of the future. They will as well produce their proportion of merchant vessels, and in addition we now have all of the new shipyards.

Our shipyards have produced during the year a greater tonnage of merchant vessels than was ever heretofore in any one year produced in the yards of the greatest shipbuilding nation in the world.

The United States have spent and contracted to spend enormous funds, primarily to help put down the war and incidentally to place upon the seas a great tonnage under their flag.

Now that the inevitable end of the great war is rapidly approaching, the problems following the destruction and disorganization caused by the war demand the attention of our best ability and judgment. I pass all of the problems not in themselves specially pertaining to this Society. The one great problem for us to consider is that of the future of our merchant marine and what is to be done for it.

You who are owners of ships and shipyards and you who design and construct ships cannot be indifferent to this question. There are at present in service, as has been stated, ten million gross tons of American merchant ships, double the amount three years ago, and there is a capacity in our yards for building in addition to the ships for the navy at least three million gross tons per annum. Some of these yards, of course, build wooden ships which will be useful coastwise, if not across the seas.

When the war is really over shall we as a nation, supinely, as in the past, permit the other nations of the world to carry our entire commerce overseas?

It is incredible that any administration of the United States Government shall thus sacrifice the great funds and efforts, individual and collective, that have been expended in the past two years to build up facilities, to educate men, and women, too, in order that we may have and operate ships of our own; and if there are laws upon our statute books that prevent our reasonable operation of ships, they must be amended; if our loading, unloading and other port facilities are not what they should be, they must be changed; if there is anything which interferes with our progress upon the seas, it must be removed, and if there is anything yet lacking to advance this progress, even government ownership, or private ownership aided by a judicious government, it must be developed not for the advantage of any section or coast, but for the needs and advantage of our whole nation.

I am quite aware that these are most general statements and that I have suggested no special plan for bringing about that which is so much to be desired. Frankly, I must say that the questions involved are too much for one man, and the result desired can only be accomplished by proper coordination of those out of whose experience may be determined the best course to follow.

I recall at this point the wild statements made early in 1917 as to our promised ship production. No one familiar with our business was deceived; but when the summer of that year had passed, and numerous yards had been established and the great number of fabricated ships had been contracted for, our hopes were raised that there would be during this year 1918 a production of ships in our yards considerably greater than ever before produced in one year in any other single nation. We have not realized these fond hopes, but I ask you to consider what has been done in the country besides building ships.

Think of the enormous tasks accomplished in the past twenty months, three of which were the hardest winter months ever known in this country. Think of the cantonments and camps built for soldiers, sailors and aviators; the raising of an army of three million men

and the manufacturing of clothes, guns, artillery, munitions and supplies for such army; the despatching "over there," with the aid of our allies, of an army of two million men and all of the impedimenta of war besides; the further extraordinary work done by the several aid associations, the Red Cross and others and with it all, the raising of a fourth liberty loan of six billion dollars in three weeks, following the raising of nine billions in the other loans and every one of the loans oversubscribed.

Think of these accomplishments, far greater than were performed by any nation in the same period of time; and while all of this program was being executed there were built numerous shipyards and about two and one-half million gross tons of merchant ships delivered in twelve months—at least one-half million more than produced by the greatest shipbuilding nation of the world in the year of its largest production—and you will conclude that this additional accomplishment is worthy not only of notice but of great praise.

We must look to the future with optimism. In a Washington office hangs a placard which says:—"It can't be done! BUT HERE IT IS." We must neither think nor say it can't be done.

No citizens of this great land are more interested in producing a merchant marine than yourselves. We naturally belong to the coasts and the Great Lakes. We must be optimistic that we may exert our own great ability to its utmost. We must carry our optimism to our inland citizens lest they forget the lesson of how much they needed ships in the years 1914 and 1915. We must be Americans and think in American terms.

Paraphrasing a quotation used at our banquet a year ago I repeat, "We have performed gigantic tasks more rapidly in all the circumstances than could any nation in the world. We shall build ships; we shall secure and train officers and sailors," and we shall establish and keep forever a merchant marine on the seas of the world, "for the sea was in our fathers' blood, the ocean is our birthright." This also gigantic task we shall perform.

[NOTE.—It is to be noted that in this address ship tonnage is only expressed in registered gross tons, as determined by official measurement.

A cargo vessel of any given gross tons has approximately a deadweight ton capacity of one and one-half times the gross tons; therefore, the production of 2,500,000 gross tons in the year 1918 means approximately 3,750,000 deadweight tons.]

THE PRESIDENT:—The next business in order is the reading of the papers. The first paper to be read is entitled "The DeLamater Iron Works—The Cradle of the Modern Navy," by Mr. H. F. J. Porter, Visitor.

MR. H. F. J. PORTER:—Mr. President and gentlemen, I esteem it a great honor and privilege to present this paper to you; the honor in having been asked to gather together the records of these old iron works, and the privilege of presenting them to you for your records. I have never considered myself the proper man to perform this task, because I was only a young fellow when I went to the works, and the works had already passed through three-quarters of their existence, but time was passing and there seemed to be no one else to do it, so when I was invited to do it I willingly accepted the task.

Now, Mr. President, if you will allow me, as long as this paper is simply one for record and will not require discussion, I will present it merely in abstract. I have a short summary of the contents here, which I can read in a few moments, but I should like very much if the members of this Society would, at their leisure, read the paper and add to it, if they can, in order that your Society may have a complete record of these old works.

Mr. Porter then read the abstract of his paper.

THE DELAMATER IRON WORKS—THE CRADLE OF THE MODERN NAVY.

By Holbrook Fitz John Porter, M. E., Visitor.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

In the late thirties of the last century, when Martin Van Buren was President, Wm. L. Marcy, Governor of the State, and Aaron Clark, Mayor of the city, New York was pretty much country above 14th Street, and the section called Greenwich Village, extending from Hammersley Street (which later became West Houston Street) up to 14th Street, and from Washington Square to the North River, was a thriving suburb. There were no street cars in those days, but stages plied between the Battery and the village, carrying those who lived in the latter down to business and back again every day.

A pile bulkhead skirted the river front with here and there a wharf or pier jutting out into the stream and ships tied up to these for repairs made by local "engineers" and "machinists" who kept their kits at home.

Among the former was James Cunningham, who lived at 387 Washington Street, between Beach and Hubert Streets, and had made a competence at his work, which he invested in ships of his own, some of which went around the Horn and up the Pacific Coast as far as San Francisco. Then there was Adam Hall, another engineer who lived across the street at 386, who worked with Cunningham. They hired a little shop together and hung up the sign of "Cunningham & Hall" at the corner of West and Laight Streets, where they took orders, did some machining and blacksmithing, and kept their tools and supplies. Business thrived so that they soon needed more of an organization, so they asked Peter Hogg, a draughtsman and mechanic who lived a block above at 507 Washington Street, to join them. After working together for some months and requiring more room, they decided to make a larger venture and seek more commodious quarters.

So in 1838, finding a suitable location at 260 West Street, between Vestry and Laight Streets, they established the "Phoenix Foundry." Cunningham moved to 86 Laight Street around the corner so as to be on hand and superintend things. Next to Hogg at 509 Washington Street lived William DeLamater, a bookkeeper, and Hogg, knowing him to be a good man at figures, got Cunningham to take him as cashier and confidential adviser for the concern, and his son Cornelius H., then in the hardware firm of Swords & Company, as clerk. Hall moved around to 34 Vestry Street so as to be on hand if needed for a hurried job. The best mechanics they knew were placed in charge of the men they employed. Alexander K. Rider, a young mechanic, was given charge of the foundry, John McCurdy was made fore-

man boilermaker, and Jacob S. Warden draughtsman. Besides repair work they started building boilers and engines for side-wheel steamers for river and coastwise service, and the shop, being the only one of the kind, grew rapidly and soon gained a reputation for doing good work, attracting attention from near and far.

In the fall of 1839 there came to New York from England, where he had made a name for himself as a brilliant young engineer, Captain John Ericsson, born July 31, 1803, in Sweden. He was a little over thirty-seven years old, handsome and of fine physical development, a member of a wealthy mine-owning family in his native land, with a military title awarded to him on account of service in the Royal Artillery and his knowledge of military engineering acquired by hard study and experiment. Captain Ericsson located himself at the Astor House, then recently built and known locally as the Park Hotel. He had come over at the solicitation of Lieut. Robert F. Stockton, U. S. N. retired, a man of wealth and influence, who was building the Delaware and Raritan Canal in New Jersey and had gone to England to raise money to complete the project in which his own and his family's fortunes were invested. Hon. Francis B. Ogden, of New Jersey, U. S. Consul at Liverpool, had become highly impressed with the engineering ability of Captain Ericsson, placing special value on one of his recent inventions, the propeller, which the English Admiralty had condemned as impractical. Ogden recommended him to Stockton as a man who would be of value to him in the construction of vessels and machinery for his canal and to the U. S. Government in the development of hulls and engines for the Navy. As an inducement to Ericsson to come to New York, Stockton assured him that he would secure for him a commission to build one of three steam frigates authorized by Act of Congress on March 3, 1839, and as an earnest in the matter, Stockton gave him an order before leaving England for two iron steamboats to be fitted with Ericsson's engines and propellers. One of these was named the Stockton and came to this country under sail and was the first direct-acting screw propeller ever built.

After Ericsson had located himself in New York, Mr. Samuel Risley, one of the Greenwich Village mechanics who had been recommended to him locally, became his draughtsman and proposed that he give his work to the Phoenix Foundry, and there he set up a model of the steam frigate which he had made before leaving England and had brought over here with him.

This introduction proved to be a most fortunate circumstance, for then and there began a business connection which later developed into a close relationship and which proved not only of vital interest to Ericsson and the works during the lifetime of both, but to the nation and the world at large.

Especially close was the intimacy of Ericsson and young DeLamater, then about twenty years of age, and rarely in later years did either take a step in the nature of a business venture without consulting the other.

The Government was not yet ready to place the order for the steam frigates, but Ericsson was promptly commissioned by Stockton to build some iron canal boats for his New Jersey Canal, and some of them which Ericsson arranged to have built

at the Phoenix Foundry were the first iron boats built in this country. When they were launched, large crowds gathered at the dock to see them sink and went away wondering why they floated. Thus early in its career did this plant become a pioneer in initiating advance in engineering practice, and especially in the marine field, in which it subsequently held a dominant position.

Ericsson was not idle in obtaining orders on his own account. He soon secured other work and arranged with the Phoenix Foundry to construct it. He built two steam propellers, one the Vandalia, which ran between Oswego and Chicago, and this was followed by the Clarion, which plied between New York and Havana. These were respectively the first lake and ocean steamers fitted with the Ericsson propeller. Others followed fast, and before 1840 was over fifty propeller steamers had been constructed and were plying our rivers and lakes and in the coastwise service.

In 1842 Stockton secured the order for the iron frigate which he arranged to be named the Princeton after his birthplace, and he commissioned Ericsson to do the engineering work of designing the engines and hull.

Ericsson at once placed the order for the engines and propellers of the Princeton with the Phoenix Foundry and the hull was constructed at the navy yard in Philadelphia. This was the first iron steamboat built in this country and, with its propeller wheels and engines wholly below the water line, presented a design which was at once adopted by this and all other countries for naval vessels of the future. In this beginning, which was later followed by further advances just as radical, these works should easily lay claim to being "the cradle of the modern navy."

The Princeton, so far as every detail of construction by Ericsson was concerned, was an absolute success. One of the saddest occurrences, however, in the history of the U. S. Navy happened on one of her trial trips, February 28, 1844. Ericsson had constructed in England, and brought with him to this country, a 12-inch wrought iron gun of his own design with the butt reinforced with heavy wrought iron bands shrunk on. This gun had been subjected to the severest tests and to-day is in the Brooklyn Navy Yard, a monument to the knowledge of the science of ordnance engineering possessed by Ericsson. The ball of this gun weighed 216 pounds and with 30 pounds charge of powder was thrown 3 miles. Stockton planned a gun along certain lines which Ericsson would not approve, and the two, called respectively Oregon and Peacemaker, were placed on the Princeton. The latter's trials on the Potomac were scenes of great rejoicing. On one of these, the cabinet of President John Quincy Adams, both Houses of Congress and many distinguished guests were on board. The guns were repeatedly fired. Just at dusk a call was made for one more discharge, but the admiral commanding declined to order it. Appeal was made to the Secretary of the Navy. His assent was considered an order and the Peacemaker was fired. The gun burst, killing two members of the cabinet, Secretary of State Upshur and Secretary of the Navy Gilmer, Senator Virgil Maxey, Capt. Beverly Kennon, Col. David Gardiner of Gardiner's Island, and a

colored servant of the President whose name is not recorded. Several others were wounded. Colonel Gardiner's remains were carried to the White House, which event resulted later in the marriage of his beautiful daughter to President Tyler.

Stockton sought to lay the blame for the disaster on Ericsson, but Ericsson's letters to Stockton protesting against the character of construction of the gun, and pointing out its defects, were a complete refutation of the charge.

This incident resulted in an estrangement from Stockton, whose treatment of Ericsson was most uncalled for. Ericsson had left his interests in the matter of business arrangements with the Government in Stockton's hands, presuming that the latter would attend to his being paid for his engineering services as well as for the use of certain devices, patents for which he had applied and which he was introducing in the vessel. Ericsson had put in some 200 days of draughting work alone which his assistant Risley inked in and this, with his time of supervision in Philadelphia and New York, covering a period of over two years, together with his expense of travel, placed him in a position where he was in need of money. Other work was crowding upon him and demanding his time, but payments for it were not due. Stockton continuously opposed the Government's paying him, and his influence was so strong that not only did his effort in this respect succeed but he aroused a prejudice against Ericsson in the Navy which continued to exist for years.

Finally, when his funds reached the low figure of $23.00, Ericsson wrote to a friend, John C. Sargent, in his extremity, but apparently secured no relief from this source, for Ericsson wrote to him, September 16, 1846:— "I received your letter of the 14th yesterday afternoon and opened it with a trembling hand. My worst fears were realized and I turned nearly crazy for a few minutes. In my despair I resorted to the expedient of asking DeLamater to help me and he has done so, for to-day appropriating the funds he has for meeting a bill at the end of the week. Now if in addition to my anxiety already experienced I should ruin the young man's credit by not being able to refund the money by Wednesday, I shall have to cut my throat."*

All that Ericsson was paid, for what was probably the greatest advance in naval architecture which ever took place at one time, was $1,150.00, which was paid on account as the work proceeded.

Ericsson was thoroughly outraged by this treatment from the Government, but he would never urge payment himself or allow others to press his claim. It was not until after his death nearly 50 years later that his executors succeeded in having a claim for $15,000.00 adjudicated by the Court of Claims and a bill authorizing its payment passed by Congress.

In this account of Ericsson's early experiences it would seem as if the Phoenix Foundry had been lost sight of, but after the entry of Ericsson into the affairs of the foundry he became so important a part of its personnel that what was his was their interest, and their affairs were indissolubly associated.

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*Col. Wm. C. Church's "Life of Ericsson."

Going back to the story of the plant itself: in 1842 Mr. Cunningham decided to go to California, which was rapidly developing as a state and where his shipping interests were increasing, and having no kin who wished to take up the business, he called in his superintendent, Hogg, and young DeLamater, who were then both about twenty-one years of age, and asked them if they would take the business off his hands. Each stated that he had no capital to carry out such a venture, but Mr. Cunningham, having confidence in their industry and integrity, offered to make the transfer an easy one and persuaded them to undertake it together, arranging to accept notes for $25,000, payable in one, two, three, four and five years.

With some $600 in hand and letters of endorsement from Mr. Cunningham to the various supply houses with which he had been doing business, the young men started out together in 1842 to conduct the fortunes of the Phoenix Foundry under the name of Hogg & DeLamater. Hogg moved down from 507 Washington Street to 59 Vestry Street so as to be near at hand, as Cunningham had found the need for close proximity existed, and the new firm started.

James Cunningham was a thrifty Scotchman with a pioneering spirit. He had a savings bank in Boston before coming to New York and his venture in the Phoenix Foundry was secondary to his shipping interests. He had Ericsson fit up the Senator, one of his vessels, as a steamship, and it was the first of that type to round the Horn. He sailed for California with his family and became an important element in the development of San Francisco and made a large fortune. Later his eldest daughter Jane sailed to join him and on the voyage became acquainted with a fellow passenger by the name of Darius O. Mills who was a banker in San Francisco and they subsequently were married.

Mr. Mills rose to be a great financial figure in California and later in the world at large. In New York City the Mills Building, a modern office building in the center of the financial district, and the three Mills Hotels, located respectively on the lower East and West sides and in the uptown center, for the accommodation of the working-man, attest the diversity of his character.

With the Phoenix Foundry business thrived under the new regime. Times were good and there was an increasing demand for steam-driven machinery. Ericsson brought in work, some of which were commissions and some were ventures of his own. Ericsson's business relations with the firm were of such a nature that the financial risk of these experimental enterprises were largely shared equally. By 1844 he had become the guiding engineering spirit of the place and moved his residence up to 95 Franklin Street to be closer to his work, some of which demanded his constant supervision and even then did not always prove to be as successful as he had expected.

For instance, there was the Iron Witch, the first iron steamboat built complete in New York City. It had compound steam engines, and twin-screw propeller wheels. It was run as a passenger boat between New York City and Albany, but making only 17 miles per hour did not prove satisfactory and was withdrawn from service.

Ericsson had invented a hot air engine which, on account of its simplicity and safety of operation, could be run by anyone, and the manufacture of these was taken up and developed into a considerable business of itself, especially for pumping water to the upper stories of houses. "Ericsson Pumpers" they were called.

The success of this type of power emboldened the firm to endorse a proposal of Ericsson's to build a side-wheel vessel to be operated by it, and the Ericsson was built, having four hot air engines with cylinders 14 feet in diameter. It would be quite a piece of work to bore cylinders of that diameter even now and have them true enough to hold hot air under pressure, but they did it, and the vessel made one trip under her own power to Washington, D. C., and back. It did not prove to be satisfactory, however, and the engines were removed and replaced by inclined steam engines working on the same shaft.

There was plenty of work of all kinds crowding into the foundry, so much so that an extension to the corner of Vestry Street was made in 1849 and 1850, but as the amount of land available in that locality was extremely limited it was evident that this would be only a temporary expedient, and so they began to cast about for a larger site, one if possible located on the water front.

Such a site was found finally at the foot of West 13th Street, extending from Tenth Avenue to the river. Much of this site was under water and it required a great deal of fill to make land and have it solid enough to carry the weight of the heavy tools which the firm then possessed, many of which had been imported from England, as the machine tool industry in this country had not yet advanced sufficiently to produce as large or substantial ones as were needed. It was a gradual shift which took place, therefore, and for a couple of years, while the transfer was being made, work was done at both sites. In 1851 the office was moved uptown and Mr. DeLamater changed his residence to 302 West 14th Street, next to the corner of Eighth Avenue. The following year Mr. Hogg moved to 244 West 13th Street, between Seventh and Eighth Avenues.

As long as some of the plant remained at the old site it was known sometimes as the Phoenix Foundry and sometimes Hogg & DeLamater's Foundry, but after the transfer it became known as the Hogg & DeLamater Iron Works.

A story is told by Colonel Church in his "Life of Ericsson" of one of the latter's visits to the new shop. This was on Thanksgiving Day, 1854, which does not seem to have been a holiday either for workmen or boss. While talking with an engineer who was testing one of his engines, he noticed one of the workmen reach out to feel if the brasses of a vibrating connecting rod were heating, and called to him to be careful or he would lose his hand, but involuntarily his own hand went out and his finger was cut off. Turning to DeLamater, he exclaimed, "See, Harry, what I have done!" Picking the piece from the floor, he dropped it in his pocket and tied a piece of tape around the stump to stop the hemorrhage. Then he drove home, where, without taking ether, he had a doctor make a proper amputation.

Ericsson was 5 feet 7½ inches high, broad-shouldered and long-bodied from his waist up, so that when sitting he gave the impression that he was tall; he weighed

178 pounds. People of that build are usually strong, and in this regard he was no exception. One day when he was going through the foundry he saw a casting which was intended for one of his engines and, looking it over, he concluded that it was not sound and ordered one of the men to test it with a sledge. This the man did, but Ericsson was not satisfied and told the men to carry it over to another part of the foundry where he could rest it on two castings and then strike it. The men said it was too heavy to lift, whereupon Ericsson picked it up and carried it over to the place himself and, taking the sledge, broke it with one blow, disclosing the flaw which he suspected was there. After he had gone, the men placed the pieces on the scales and found them to weigh 592 pounds. He was fifty years old at the time.

In the transfer of the plant uptown, more changes took place than were apparent in the mere change of site. The phenomenal success and growth of the plant induced some of the younger, more ambitious and venturesome mechanics connected with it to strike out in a similar direction for themselves.

Alexander K. Rider, who had charge of the foundry, secured a partner and started a small plant at the foot of West 59th Street under the name of Rider & Ward. They were successful for several years till an accident occurred in which Rider was so seriously injured that he was rendered helpless for over a year and remained an invalid for the remainder of his life.

John McCurdy, who had charge of the boiler shop, took Jacob S. Warden, the chief draughtsman, and started business at 276 West Street under the name of Murphy, McCurdy & Warden, where they became a well-known fixture for many years.

Men already in the plant, whose qualifications for advancement had been recognized, were promoted. Jerry Mulford was made superintendent. Wm. Sibley was placed in charged of the foundry. He died soon afterwards, however, and his brother Fred took his place and remained there permanently. Frank Ramsey was made foreman of the boiler shop. He was one of four brothers—John and Philip in the pattern shop and William in the machine shop. Charles Van Wagenen became foreman of the pattern shop.

All these men lived in the neighborhood, as means of transportation were very poor. Thirteenth Street was pretty far uptown in the early fifties. Few horse car lines ran that far and, as there were no cross town cars, if work was required on a vessel in the East River the men had to walk there. It was not until 1855 that a line of horse cars was run up Hudson Street and Eighth Avenue as far as 30th Street, and later to 53rd Street, with occasionally a car to 59th Street.

The new site covered land on both sides of 13th Street. Between 13th and 14th Streets a shipyard was located and many wooden and iron steamers were built there and launched from it, and the boilers and engines were made in the shops behind it and across the street.

They built the iron steamer Matanzas for Mora & Nevarro in the West Indian trade, and many others, and steam outfits for the Mallorys, shipping merchants, who built wooden ships at Mystic, Connecticut, running to Fernandina and Key West, Florida, New Orleans, Louisiana and Galveston, Texas.

Ericsson's caloric engine business was still thriving and this type of power was applied to fog-horns in lighthouses where fresh water for power purposes was scarce. When the largest of these, constructed for the lighthouse at Montauk Pt. Long Island, was tested in the shop it caused such a vibration to the building that it had to be moved so that the horn could be located out of doors.

There came to them at this time a good deal of work for sugar refineries, consisting of boilers, engines, tanks, etc., and in one of their orders they equipped the new refinery of Moller & Martin at Corlears Slip at Grand Street and the East River. When this work was completed in 1858 Mr. Hogg was offered a partnership in the sugar-house firm which he accepted and left Mr. DeLamater to run the business alone, moving his residence to 59th Street, Brooklyn.

Mr. DeLamater then changed the name of the works to The DeLamater Iron Works, which it continued to bear thereafter. He moved his home to 333 West 15th Street at this time. An advertisement of the time reads:—"Cornelius H. DeLamater Iron Works, Manufacturers of Engines, Boilers, Castings, Machinery, etc."

When the Civil War broke out these large and well-equipped shops possessed special facilities for war work, and Mr. DeLamater promptly offered them to the Government for such work as might be needed. He became a charter member of the Union League and took an active part in the patriotic services rendered by that body.

Knowing Ericsson's mental equipment in ordnance engineering science, Mr. DeLamater had frequent conferences with him about the work they would be able to perform for the Government.

In 1854 Ericsson had sent to Napoleon III plans for an armed ironclad turreted steamer differing from what is known as the original Monitor only in that the turret had a rounded dome. The emperor did nothing with them, but he was so greatly interested that he acknowledged them personally and sent Ericsson a gold medal testifying his appreciation.

Mr. DeLamater knew of this and they talked over the possibility of utilizing the design in the then existing emergency. Ericsson said that the original plan was the conception of his boyhood days, but that he had given the subject thirty years study and would willingly offer his matured ideas to the Government if he could be assured of an unbiased reception, for he knew of the prejudice still existing against him in the Navy Department since the Stockton episode.

Then came the word that the Southern Confederacy was fitting out the ironclad Merrimac with which they expected to capture every northern port and seaboard, destroy our commerce and compel the surrender of Washington.

On August 3, 1861, President Lincoln approved an act appointing a board to determine upon building ironclad steam vessels. The board was named August 8. An advertisement inviting proposals was promptly published, and Mr. DeLamater at once called on Ericsson to determine upon a method of approaching the Government. Ericsson was disinclined to take the initiative, realizing that the authorities were fully informed regarding his capabilities and yet had totally ignored him, and

he disliked placing himself in a position to be rebuffed. Mr. DeLamater argued that a letter addressed direct to President Lincoln would insure him a fair hearing, but it was twenty-one days after the advertisement appeared before the following letter was written and dispatched:—

"NEW YORK, *August* 29, 1861.

"SIR:

"The writer, having introduced the present system of naval propulsion and constructed the first screw ship-of-war, now offers to construct a vessel for the destruction of the rebel fleet at Norfolk, and for scouring the Southern rivers and inlets of all craft protected by rebel batteries. Having thus briefly noted the object of my addressing you, it will be proper for me most respectfully to state that in making this offer, I seek no advantage or emolument of any kind. Fortunately I have upward of one thousand of my caloric engines in successful operation, with affluence in prospect. Attachment to the Union alone impels me to offer my services at this fearful crisis—my life if need be—in the great cause which Providence has called you to defend. Please look carefully at the enclosed plans and you will find that the means I propose to employ are very simple—so simple, indeed, that within ten weeks after commencing the structure, I would engage to be ready to take up a position under the rebel guns at Norfolk, and so efficient, too, I trust, that within a few hours the stolen ships would be sunk and the harbor purged of traitors. Apart from the fact that the proposed vessel is very simple in construction, due weight, I respectfully submit, should be given to the circumstances that its projector possesses practical and constructive skill shared by no engineer now living. I have planned upward of one hundred marine engines and I furnish, daily, working plans made with my own hands, of mechanical and naval structures of various kinds, and I have done so for thirty years. Besides this I have received a military education and feel at home in the science of artillery. You will not, sir, attribute these statements to any other cause than my anxiety to prove that you may safely entrust me with the work I propose. If you cannot do so then the country must lose the benefit of my proffered services. If, on the other hand, you decide to act, please telegraph and I will at once wait upon you in Washington. I respectfully submit that in the former case you return the plans, honored with your signature, to testify that I have discharged the duty of laying this important matter before you.

"I cannot conclude without respectfully calling your attention to the now well-established fact that steel-clad vessels cannot be arrested in their course by land batteries, and that hence our great city is quite at the mercy of such intruders, and may at any moment be laid in ruins, unless we possess means which, in defiance of Armstrong guns, can crush the sides of such dangerous visitors.

"I am, sir, with profound respect,

"Your obedient servant,

"J. ERICSSON.

"To His Excellency,

"Abraham Lincoln,

"President of the U. S."

One of the first sets of plans recommended for adoption by the board was presented by C. S. Bushnell, and he was awarded a contract to build the vessel known as the Galena. He consulted DeLamater, many of the naval men having doubted her ability to carry the stipulated amount of iron protective plate. Mr. DeLamater advised him to confer with Ericsson, whose opinion he was satisfied would settle the matter definitely and correctly. He called on Ericsson, laid the matter before him, and was requested to return the next day for his verdict. It was entirely favorable. Captain Ericsson then produced his duplicates of the model and plans of the ironclad steamer he had sent to Napoleon. He found a most willing champion in Bushnell, and gave him both plans and model to present at Washington.

Bushnell, knowing that Secretary of the Navy Welles was at Hartford, proceeded there by first train. The Secretary urged all possible despatch to have the plans submitted before the board, and the next day Bushnell was in Washington. He was joined by John A. Griswold and John F. Winslow, both of Troy, and friends of Secretary Seward. The latter gave them a strong letter to President Lincoln, who went with them to the Navy Department the next morning. Confronted with the novelty of the proposal, some advised trying it, some ridiculed it. It was at this conference that President Lincoln remarked:—"All I have to say is what the girl said when she stuck her foot into the stocking: 'It strikes me there's something in it.'" The next day the board condemned the plan. Bushnell labored with them, and won over Admirals Smith and Paulding, who promised to report favorably if Captain Davis would join them. Captain Davis told Bushnell to "take the little thing home and worship it, as it would not be idolatry, because it was in the image of nothing in the heaven above, or on the earth beneath, or in the waters under the earth."

Bushnell felt the only way to succeed was to have Captain Ericsson present in Washington. He came to New York, saw Mr. DeLamater, and together they went to Ericsson's home to consult him. The exact facts were not given to Ericsson, but he was told that some explanations were needed that he alone could make. He went to Washington that night. As soon as he appeared before the board, he was told that his plans had been rejected. His indignation impelled him to withdraw at once, but he stopped long enough to ask why they had come to that conclusion. He was told that the vessel lacked stability. His technical skill being impugned, he explained with elaborate demonstration and so convincingly that Commodore Paulding said frankly and generously:—"Sir, I have learned more about the stability of a vessel from what you have said than I ever knew before." He was told the next day by Secretary Welles that a contract would be awarded, and was asked to proceed at once with the work. Chas. W. MacCord was his daughtsman and worked day and night on the plans. The contract was signed October 25. The keel of the Monitor was laid by Thomas F. Rowland at the Continental Iron Works, Greenpoint, Long Island, on the same day. Steam was applied to the engines at the DeLamater Iron works, December 30. Ericsson's work during those three months was herculean. Not only the necessary labors, but the

worries from continued doubts sent from Washington, required almost superhuman power.

The Monitor left New York harbor March 6, 1862, commanded by Lieut. Commander John L. Worden, arriving at Hampton Roads on the morning of the 9th, and before the sun set that day the famous battle of the Monitor and the Merrimac was fought. The Monitor conquered the Merrimac before she had been accepted by the Government and Captain Ericsson was permitted to receive his final voucher on March 16, one week after he had demonstrated that the doubts at Washington were without foundation.

The war vessel was changed in one day. The Monitor type became the war vessel of the world.

Besides Commander Worden, who maneuvered the vessel and directed the battle from the conning-tower, the crew of the Monitor consisted of:—Lieut. Samuel Dana Green, 1st Masters Louis W. Stodder and John J. W. Webber and Acting Master Howard, all in the turret, handling the guns; Asst. Surgeon Daniel C. Logue, Quartermaster Peter Williams, Paymaster W. F. Keller, Chief Engineer Alban C. Stivers, U. S. N., 1st Asst. Engineer Isaac Newton, 2nd Asst. Engineer Albert B. Campbell, 3rd Asst. Engineers R. W. Hands and M. T. Sunstrum, Patrick Hannon, 1st class seaman; Hans Anderson, sailor; Geo. S. Geer, fireman; Daniel Toffey, clerk; Wm. H. Nichols, wardroom clerk (colored).

But it should be known that the men who actually operated the boilers and engines of the Monitor were the workmen from the DeLamater Iron Works who had built them, were familiar with them, and were paid by Mr. DeLamater. After the battle they returned to the works and continued their daily routine of duty as if nothing unusual had happened. Their names are, however, lost to history, as were those of many others connected with these works who performed equally important service for the benefit of the country and the world of industry at large.

A note in the file of the Navy Department of the time reads:—"The Monitor —price, $275,000; time, 100 days; length of vessel, 172 feet; breadth of beam, 41 feet; depth of hold, 11½ feet; draught of water, 10 feet; displacement, 1,255 tons; speed per hour, 9 statute miles. Sunk in gale off Cape Hatteras, December 31, 1862."

The success of the Monitor naturally focused the attention of the U. S. Government on Ericsson and the DeLamater Iron Works, and within a week they received a proposition to build six vessels of the same design but of various sizes, some of them much larger than the Monitor. Whether it were idolatry or not, the world was worshipping at its shrine.

At this time something occurred which caused Captain Ericsson to leave his residence at 95 Franklin Street and move to 36 Beach Street, a couple of blocks farther uptown, where he fitted up a draughting room in which he drew the plans of these monitors and of all his subsequent work, and where he spent the remainder of his life. Not being in affluent circumstances at the time, as he was accustomed to spend his money freely in experimenting with his inventions, Mr. DeLamater proposed to purchase the house for him, but he courteously declined to accept the offer.

Propositions even from the Government are not orders, and it was over a year before the first one for another vessel of the monitor type materialized. This was for the Dictator, a much larger vessel than the Monitor, and it was built complete, hull, engines and all equipment, at the DeLamater Iron Works.

In contracting for the Dictator, the department conferred upon Ericsson the extraordinary privilege of constructing the ship and her machinery after his own plans. As an evidence of Ericsson's mastery of his work, one fact will serve. It is embodied in the statement by the government inspector regarding the Puritan, her sister ship, the order for which followed shortly after that of the Dictator:—"I have to report that the draught of the ship at the midship section, through centre of forward turret, proved to be eleven feet, ten and three-quarters inches, while the launching plan called for eleven feet, eleven inches. Difference, one-fourth inch less draught than calculated."

The engines for the two vessels were duplicates and were built together at the DeLamater Iron Works. The hull of the Puritan was constructed at the Continental Iron Works at Greenpoint, Long Island. At the launching of the Dictator it was found that its tremendous weight had so settled the ways in the filled-in land that great difficulty was encountered, and it was only in the third attempt that the launching was successfully achieved.

The propeller of the Dictator was 20 feet in diameter and weighed 44,000 pounds, which was quite a casting for those days, and Fred Sibley, who cast it from the foundry cupola, was justly proud of the accomplishment. The steam cylinders were 100 inches in diameter, the largest made up to that time. These vessels were not finished till after the war was ended and their use was not availed of until later.

Several composite wood and iron monitors were built at the Brooklyn Navy Yard and had their boilers and engines made at the DeLamater Iron Works so that the latter had to expand through to 14th Street on one side and to 12th Street on the other to take care of all the work that fairly poured in upon them.

Mr. DeLamater never held himself aloof from his men, and anyone down to the most lowly of his employees could approach him without ceremony, and yet he was always dignified and commanded respect. On this account he was very popular with the men, and this was generally known among the masses throughout the city. During the war, the great services which he was able to render to his country emphasized his loyalty to the cause and endeared him more than ever to the people of the city.

During the Draft Riots in 1863, when the mob was burning right and left and more than one large industrial plant was destroyed, a cry was raised by some one in the crowd to "burn the DeLamater Iron Works," but the mob shouted "No," and someone proposed three cheers for Mr. DeLamater, which were given with such a good will that it was evident there was no reason for anxiety on their account.

In 1864, to take care of all the outside work, which had become as voluminous as the shop work, Jerry Mulford was made outside superintendent and George H.

Reynolds came to the works and was made general superintendent and chief engineer. Hugo B. Roelker was made chief draughtsman and James Miller head foreman.

In the early forties Robt. L. Stevens of Hoboken, one of the foremost engineers of his day, conceived the idea of a floating battery with cannon mounted on deck and operated by chains from below the deck, which was ironclad, as well as the sides for some distance down below the water line. Considerable mystery surrounded its design, and its construction was shielded from view by a shed over the yard at Hoboken which completely inclosed it. Stevens and his draughtsman, Myers Coryell, worked on it for some years, but it was never completed.

As fast as construction reached a point where it was considered invulnerable to the impact of any existing gun someone would develop a gun with greater penetrating power and work on the battery would be halted; then an overhauling would take place until its original design was entirely changed.

At the death of Mr. Stevens, his son, Edwin Stevens, continued its development under the supervision of John Newton, Chief Engineer, U. S. N., who had the work performed at the DeLamater Iron Works, but finally it was turned over to the State of New Jersey and Governor Theo. F. Randolph in 1869 appointed a commission composed of Gen. Geo. B. McClellan, Gen. Fitz-John Porter, and Wm. F. Shippen to study its construction and report their recommendations. This commission reported unfavorably upon continuing its development and some years afterwards the DeLamater Iron Works was given the order to dismantle it, which work was directed by Mr. Geo. H. Reynolds, who practically blew it apart with dynamite, much to the terror of the citizens of Hoboken, who got out an injunction to stop him. But Mr. Reynolds saw to it that by the time it was issued the principal work had been accomplished, and it made no difference.

In 1864, Mr. Alexander Holly, a well-known metallurgical engineer, returned from England, where he had gone in the interest of the Rensselaer Iron Works of Troy, N. Y., to investigate the Bessemer process of making steel then just developed. He placed an order with the DeLamater Iron Works for a blowing engine for the converter of the plant, which was constructed at Troy, and the first steel castings made in this country were cast in an experimental furnace at the Troy works and used in the construction of this engine. A composite wood and iron coast survey steamer was built and launched at the works at this time.

In 1865 Mr. A. K. Rider, previously referred to, had recovered his health sufficiently to be able to become active again and returned to the shop. His son, Thomas J. Rider, a husky lad of eighteen years, came with him and served an apprenticeship in the shops and finally found a place in the draughting office under Roelker. The father had invented a cut-off valve for steam engines and this Mr. DeLamater took in hand and exploited with Mr. Rider in charge. Quite a business in standard and stock sizes of this engine was developed.

Mr. Rider possessed a very inventive mind and he and his son proved to be great acquisitions to the personnel of the staff, the father designing and the son

making the drawings. He devised a method of sweeping propeller wheel moulds in loam which has been in use ever since. This not only eliminated the expense of an elaborate pattern but developed a truer screw. The works became famous for its propeller wheels after this, and for many years it probably turned out more castings of this type than all the foundries in the country put together, running over one thousand a year.

In 1867 Mr. DeLamater decided to take a respite and perhaps retire from business altogether. He placed David M. Ripley in charge of the office and made Jerry Mulford general superintendent of the works. Mr. Reynolds became consulting engineer for several outside interests, notably the Zalinski Pneumatic Gun Company, and acted only in the same capacity with the works. After a year's absence Mr. DeLamater became restless and responded to the solicitation of Captain Ericsson and took up the reins again.

Meanwhile Captain Ericsson had developed a new caloric engine for pumping water. The city was growing rapidly and Croton water would not run even to the third story of the buildings. Land values were increasing, causing people to build higher houses, and of course it was necessary to have a means of supplying water to their upper floors. The only available plan at that time was to have a tank on the roof and an engine in the basement. The engine had to be absolutely safe and reliable and simple enough to be attended to by the janitor or his wife who, as a rule, were rather an ignorant lot. The caloric engine answered these conditions perfectly, so between "Ericsson Pumpers" for the smaller sizes and Rider's hot air pumping engines for the larger, they did a business of about 12,000 in New York City alone. Alex. Miller, son of the head foreman, handled the Ericsson caloric engine and Tom Rider had charge of the Rider steam engine and the Rider hot air pumping engine. All this time they were doing a lot of marine work, building new engines and boilers and repair work.

After a while Alex. Miller left the works, and Tom Rider was given charge of all the caloric engine work. Rider wanted to improve the efficiency of the Ericsson Pumper, but Mr. DeLamater strongly opposed tampering with it on account of his confidence in Captain Ericsson's ability. Finally, however, he allowed him to experiment with it and the result was most gratifying, for he increased its pumping capacity over 80 per cent.

Alexander Rider also developed a gas engine, and it may be interesting to note that he was the inventor of the method of igniting the gas with a spark generated by a dynamo which is now in general use in all internal-combustion engines.

In 1864, A. P. Robinson, an engineer, had designed a steam subway somewhat after the character of the London subways, but he did not develop it. This was followed by the Beach pneumatic transit system of subway construction, projected by Alfred E. Beach, proprietor of the *Scientific American,* who succeeded in obtaining a franchise to install two small tubes side by side for transporting packages from the City Hall up Broadway to Harlem. Beach exhibited an experimental section of a tunnel 9 feet in diameter in 1867 at the American Institute Fair in Ar-

mory Hall, 14th Street and Sixth Avenue, with a car for passengers operating forward and backward through it, propelled by fans, one at each end of the tunnel, alternating by pressure and exhaust, and later began construction of a tunnel of similar design in Broadway at Murray Street. When his attention was called to the difference in design between the one large tube as constructed and the two small ones mentioned in the franchise, Beach said he would put the two small ones inside the large one some time, but only a short section was ever completed.

In 1868 Charles T. Harvey, an engineer who subsequently became known as "the father of the elevated road," took out patents for a road of that character to be operated by a cable with power developed by stationary engines located on the ground. The cable sections extended over some 1,500 feet of track and carried on them at intervals washers intended to strike on a boot, lowered from the car. The impact of the washers on the boot would extend a spring and thus allow the car to be impelled with gradually accelerated velocity. A section of this road was built from the Battery up Greenwich Street to 14th Street and was intended to extend from there to Kingsbridge and Yonkers. This method of propulsion did not prove to be successful, and pneumatic power was considered with stations for air compressors and storage tanks placed at intervals along the road from which locomotives would be charged.

In all of this development Mr. DeLamater took great interest, offering the use of his works for experimental purposes and getting much of the work of construction.

In 1875 Mayor W. H. Wickham appointed the first Rapid Transit Commission to consider the general subject of transporting the public about the city, together with the various projects already presented, and placed on it Messrs. Jos. Seligman, Chairman, Lewis B. Brown, Chas. J. Canda, C. H. DeLamater and Jordan L. Mott.

Out of the muddle into which that arch politician Tweed threw everything by introducing a bill at Albany to put a masonry elevated road through the center of the city blocks, there finally emerged the New York Elevated Railroad on Ninth Avenue promoted by Harvey and designed by the engineer, John Baird, and the Metropolitan Elevated Railroad, projected by Col. Q. A. Gilmore.

Later, when the horse was supplanted by the cable on the surface car lines, the grips and castings for the cable conduit were made at the works.

In 1869 there was an insurrection in Cuba and the Spanish government, wishing to protect the island from filibusters and insurgents, sent Capt. Raphael de Aragon to Mr. DeLamater, commissioned to spend a considerable sum, but without any plan. Naturally Ericsson was consulted. He had just been studying the defense of Sweden, and at once suggested a scheme to build thirty gunboats, each armed with a 100-pounder gun mounted on her bow. He named two conditions only—to make his plans without submitting them and that DeLamater should execute the contract. The contract called for completion in eight months and they were actually completed in seven, notwithstanding the fact that the insurgents interposed many serious obstacles by litigations in the courts. The hulls of fifteen were built in Mystic, Connecticut, ten in Brooklyn and five elsewhere. The engines were

built at the works and all the equipment was assembled there and installed in the vessels. When all were completed, Jerry Mulford was delegated to find crews for them. This was not an easy job, but he went out hunting for men and finally combed up West Street in great shape, securing enough to man them, and they sailed away in two detachments of fifteen each. The works were paid $60,000 in gold for each vessel, equivalent in those days to $90,000 in currency. Some years later the designer and builder each received from the Spanish government the Commander's Cross of the Order of Isabel la Catolica, in recognition of their services.

When in 1870 Mr. George H. Robinson, a son-in-law of Mr. DeLamater, became his partner, he found that an arrangement between Ericsson and DeLamater had been in existence for many years to the effect that for whatever experiments Captain Ericsson wished to make at the Iron Works, either in building or testing new machinery, no order was to be questioned. No bill was ever rendered to Ericsson by DeLamater, and Ericsson made no charges to DeLamater for his services in furnishing plans and engineering advice at any time. In balancing the old books, items aggregating $260,000 were charged off representing a part of the expenditures, yet the arrangement was one that neither party ever had cause to regret.

I have already mentioned an instance where Captain Ericsson was in serious financial stress, but this was not always the case with him. I might mention that on one occasion, when Mr. DeLamater was in some pecuniary strait, he called upon Captain Ericsson for assistance, and received this answer to his application:—

"Dear Harry: I do not regret, and I am sure you need not, that you called on me to give you a lift in your trouble. Taking my ability for granted, there is not a man on earth you could with more propriety come to. There is, however, abundant cause for regret that my means are at present so limited that I cannot offer a lift worth accepting. The small amount of $50,000 mentioned yesterday is at your service.

"I am, dear Harry,
"Yours truly,
"J. Ericsson."

Mr. DeLamater was the most intimate friend Captain Ericsson had. They were in almost daily communication and for about twenty years Mr. DeLamater dined at Captain Ericsson's every Monday, but even his great friend "Harry" could not induce him to change his daily routine of life which kept him confined to his house continuously, and he rarely saw anyone else except the men immediately engaged on his work, among whom were Samuel W. Taylor, his secretary, and V. F. Lassoe, his superintendent.

At one time General McClellan expressed a desire to meet the man who had done so much to turn the tide of the war at a critical period. When his wish became known to Captain Ericsson, the latter said that he was very much complimented, but that he was getting to be too old to make new acquaintances and he would have to be excused. Mr. Geo. H. Robinson, who had a business appointment

at a specified hour on a certain day every week, had to be prompt to the minute, and at the end of the allotted time Captain Ericsson would rise and say:—"I am sorry you cannot stay any longer," and the conference would end.

In 1871 John T. Waring conceived the idea of a rock drill operated by steam power and came to the works to have it developed. Almost simultaneously, by one of those curious coincidences which frequently show that a common need causes minds who feel it to develop similar projects, Simon Ingersoll and Addison C. Rand brought in their more completely developed plans for manufacture. These were adopted and a considerable business in them was developed. In open work steam power was attended by little inconvenience, but in confined work in mines and tunnels the difficulties were great and a substitute for steam was sought. Ericsson was consulted and over night he produced drawings for an air compressor, and the works built many of them from this design for years. One order was for a large number of these rock drills and eight compressors cut up into parts of less than 300 pounds each for transportation on mule back and to be bolted together at the site, for Henry Meiggs, an American engineer who was then building his railroad and tunnel through the Andes Mountains above Lima, Peru. A large amount of hoisting machinery was built at this time for the Witherbee-Sherman Iron Mine, near Lake Champlain, and large steam hoisting engines for the Calumet and Hecla and other mining companies in the Lake Superior district; also gun carriages for the new 12-inch rifles at Sandy Hook, and large fog horns operated calorically for the Atlantic Coast Lighthouse Service and for similar service in England.

In 1869 there was a contract taken for the steamship City of Merida, or No. 183, as she was known in the shop. Tom Rider was delegated to make the drawings under Mr. Reynolds. Reynolds was busy with other work, however, and could not give much time to it and he had finally to go to Havana, so that Rider was left to his own resources. Mr. DeLamater placed the responsibility on him, told him it was a time contract with a forfeiture if not completed in time, and gave him full authority to go ahead.

Mr. DeLamater had the satisfaction of knowing that there were no mistakes in all the drawings made. The work was finished on time and she was the finest vessel running between New York and Havana for years, finally being burned in Havana Harbor.

Neither of the Riders, father nor son, was directly connected with the DeLamater Iron Works for some time after 1872. They went to Venezuela to a gold mine, where both caught the malarial fever and dragged themselves home more dead than alive.

In 1874 came the "Cuban Scare" and the monitor Dictator was hurried into active service. The DeLamater works had built both hull and machinery originally, and to them was entrusted her overhaul. She left for the rendezvous in charge of her consort, which lost her during a bad storm off Savannah. The consort put into that port, and it was telegraphed from there that the Dictator was lost with all on board. Mr. Robinson was summoned to the Navy Yard and requested to convey the

intelligence to Captain Ericsson. He reached his home late in the afternoon. Ericsson was overwhelmed at the news, but seeking a cause he finally concluded that her steering gear must have become disarranged. The next morning, when Mr. Robinson reached his office, Ericsson's secretary, Mr. Taylor, was awaiting him with the word that "the captain had been thinking things over and had concluded that the Dictator's steering gear could not get disarranged, and that she would report at Key West within twenty-four hours," and she actually arrived there only a few hours later than the time predicted.

In the early seventies Raoul Pictet, a Chemist of Geneva, Switzerland, had developed mechanical refrigeration, utilizing anhydrous sulphurous dioxide as the cooling mixture. He exhibited a machine at the Centennial Exposition in Philadelphia, and afterwards the Pictet Ice-Machine Company was formed and had machines built at the works. Other ice-machine designs followed, and the first ammonia ice machine which practically did continuous work was invented by a man named Smith and was manufactured in numbers. John C. Delavergne spent considerable money experimenting on ice machinery and finally formed the Delavergne Ice Machine Company, which established its own plant at the foot of 138th Street and East River in the Bronx.

In 1880 Tessie Du Motay and Auguste J. Rossi, two New York chemists, developed a binary liquid for a refrigerant composed of ether semisaturated with sulphurous dioxide, and an ice machine was developed to utilize it. An experimental plant was erected at the works and ice was manufactured there for demonstration purposes and aroused considerable interest among the public, which visited it in great numbers. Several breweries were equipped with these machines.

Then Leicester Allen came with his Dense Air Ice Machine for marine service, for chemicals were thought to be too dangerous to use on shipboard. Several types of machines were tried without much success, and in 1888 Tom Rider designed the first one used in the U. S. Navy, which is still there, being built now by Hugo B. Roelker. He used a slide valve on the compressor to eliminate the noise and wear of the poppet valves and leather packing in the pistons of both compressor and expander. Captain Zalinski, U. S. N., had his pneumatic-dynamite gun built there.

It must not be supposed, because little mention has been made of other iron works in this monograph on the DeLamater Iron Works, that as the city grew there were no others established in it which were successful and took a prominent part in the industrial advance of the times. On the contrary, there were many on both the east and west sides of the city, with all of which the DeLamater Works held the most friendly relations, one helping the other on many occasions to do work for which it was especially equipped, or when it was hurried and crowded beyond its capacity.

Fletcher, Harrison & Co. established themselves early in the forties at Vestry and West Streets, one block above where the old Phoenix Foundry was, and remained there for many years till they outgrew the site and moved to Hoboken where,

under the name of W. & A. Fletcher Company, they still do a thriving business in river boats, engines, boilers and miscellaneous engineering apparatus.

John W. Handren left the DeLamater Iron Works in 1868 and with David M. Ripley started the Albany Street Iron Works at Albany and Washington Streets. Later Mr. DeLamater's son-in-law, John N. Robins, bought Ripley's interest in the firm. The Morgan Iron Works at the foot of East 9th Street, which built the engines for the Providence and Bristol of the Fall River Line and many others; the Novelty Iron Works, Avenue D and 13th Street, which built the engines of the Arctic, Atlantic and Adriatic of the Collins Line and other early ocean steamers; and the Allaire Iron Works of T. F. Secor & Company at 455 Cherry Street, which built the engines for the Pacific and Baltic of the Collins Line, and others, were later combined by John Roach and did a large business in ocean vessels. The Quintard Iron Works at Avenue D and 11th to 12th Streets became an important adjunct to the engine and machinery manufacturing industry of the country, building the Machias, Castine, Bennington and other vessels for the U S. Navy. Tugnot, Dalley & Company had a forge at 26th Street and First Avenue and made the wrought iron shafts for these vessels under a 7-ton tilt hammer.

John N. Robins established, in connection with the Albany Street Iron Works, a dry dock at the Erie Basin and started a development in that section of Brooklyn which has continued and become of international importance.

Ericsson had an exhibit of drawings and models of all of his inventions at the Centennial Exposition which attracted world-wide attention and brought the DeLamater Iron Works before the world in a way that no amount of advertising could have done.

The works had become not only nationally but internationally known by this time and was a mecca for inventors and promoters and anyone who had an idea to be developed. Many an impecunious inventor was welcomed, encouraged and the difficulties under which he was laboring to accomplish his aim removed and success brought to his efforts. To work there was a liberal education. In those days technical schools were in their infancy, they could impart only engineering theory at the best, and students had to visit industrial plants during their course and, after graduation, spend some time in them doing whatever work they could in order to learn to apply practically the theories acquired.

Students in the mechanical engineering courses of the School of Mines of Columbia College, the Sheffield Scientific School of Yale College and other similar institutions found an open welcome by Mr. DeLamater to come and spend time in the shops under the supervision of their professors of engineering. Some of these classes would spend a week there, giving a day to each of the departments, the draughting office, pattern shop, foundry, boiler shop, blacksmith shop and machine shop, and had to pass an examination afterwards on what they had learned. Many a graduate from these schools obtained his practical experience there who would otherwise have gone through the world only half as well equipped. To Mr. Roelker, chief engineer, they were particularly indebted for the help he gave them and his patience in giving it.

I went there myself on my graduation from Lehigh University in 1878 when I was twenty years old and spent four years there. As an example of the experience a boy could get there let me refer to my own case. I spent one year in the pattern shop under Charles Van Wagenen with a follow-up under Fred Sibley in the foundry. I was assigned to Joseph Robert-Shaw, than whom there was no better patternmaker in the country. Then came an introduction to metal working by several weeks of chipping castings, during the first part of which I had to take a day off once in a while to let my hands, which had become pulp from hammering them instead of the chisel, heal up. Head Foreman James Miller used to stand over me and, I imagine, with many an internal chuckle would encourage me to "keep at it, boy; you won't be sorry some day," and I never was, for in after years there were times when I have had pride in my prowess as a chipper when, taking the hammer and chisel from a workman, I showed a gang that I could handle tools myself and thus secured a respect which I might otherwise have missed. A year followed in the machine shop finishing engine parts on machine tools and then a year in the erecting gang, assembling machinery on the floor and on outside work, installing machinery in the holds of vessels and in industrial plants. Six months of this time were spent at John Roach's shipyard at Chester, Pennsylvania, installing in the Cromwell line steamer Louisiana the engines I had already helped to assemble in the machine shop. John Baird was the designer and engineer and his daughter was his draughtsman. She used to come to the shop and the shipyard and give directions like a veteran. Then I spent a year in the draughting office, first under Roelker on general work and later under Geo. F. Meyer on ice machines, and while with him I prepared a paper on Mechanical Refrigeration and presented it in 1881 to the first annual meeting of the American Society of Mechanical Engineers at Hartford, Connecticut. Starting in at .03 cent per hour, the regular apprentice wage, my pay was increased without solicitation, as I showed any qualification for advancement. Three dollars and sixty cents seems an insignificant sum in these days to receive for six days of ten hours each, but I would have considered myself fortunate to have been permitted to work there for nothing, so valuable was the experience I was able to gain, and I now regret that I accepted an offer to take a position as engineer for a rolling mill instead of staying there longer.

During my stay the works were a veritable nursery, from which inventors who had had their ideas developed and made practical were started out in business for themselves. Among the principal mechanisms that come to my mind as having been developed while I was there are the Ingersoll rock drill, the Rand air compressor and the Delavergne ice machine, but there were many others of minor note.

The diversity of work performed may be indicated by comparing what I have already enumerated with a few others which come to my recollection. For instance, there was a wooden cannon of about 12-inch diameter, painted black to resemble iron, made in the pattern and machine shops for a vaudeville performer. A cannon fire-cracker, exploded in the iron-lined breach, was to make the noise, while a spring released by a string, pulled by the man who lighted the cracker, was to

eject a black 12-inch wooden ball which the "strong man" was to catch when it was impelled across the stage. On the evening of the first performance, all hands having been furnished free tickets, repaired to Tony Pastor's Theater, then at Spring Street and Broadway. The fire-cracker exploded all right, but the man in the excitement of the moment forgot to pull the string at the right instant, and the ball did not make its appearance till just enough interval had elapsed to spoil the illusion. This slip caused amusement rather than astonishment as intended, but they got things to synchronize better the next night and the apparatus traveled all over the country and later was developed into a gun which shot a woman into the air and she was caught in a net.

The double stage at the Madison Square Theater, located on 24th Street just west of the Fifth Avenue Hotel, was designed and constructed there. One stage was built on top of the other and was raised and lowered by hydraulic power. The scenery was set on one while the play was acted on the other, and there was little delay between acts. Mr. Reynolds had this in charge, and some of us who worked on it had free admission to see *Hazel Kirke,* a play which had a long run there.

Captain Ericsson was at work on harbor defense at this time and developed, after years of trials, the Destroyer, which carried a submarine gun and discharged by compressed air a projectile 30 feet long, loaded with 350 pounds of explosive. A test was made for General Grant and it performed what its designer claimed for it. It hit a target 10 feet square, 10 feet below the surface of the water, traversing the distance—300 feet—in less than three seconds. This was a torpedo-boat but not a submarine, and torpedo-boat destroyers are of similar design now. On the afternoon the Destroyer was launched the works had a half-holiday and beer was supplied to all the men. It was thought that Captain Ericsson might come to see the launching but he was satisfied to wait till his secretary, Taylor, and his engineer, Lassoe, same home to tell him that it was successful and that she drew just as much water as he had calculated.

John P. Holland, a school teacher, had his first successful submarine torpedo boat built there, which for years made underwater trips of long duration in the harbor and waters about New York.

Ericsson built a small steam-engine at this time which, at the rate of 1,300 revolutions per minute, drove the electric lighting plant of the works without any repair or renewal of any brasses for about twelve years.

A duplicate of this engine, beautifully nickeled and handsomely mounted, he presented to the King of Sweden.

Col. Edwin Stevens of Hoboken, whose grandfather and father built the Stevens Battery and who was himself a capable mechanical engineer, owned the ferries running from New York to Hoboken. Desiring to improve his ferry-boats he designed some with twin screws fore and aft. These were built at the DeLamater Iron Works and proved to be such a great success that practically all New York ferry-boats were afterwards of the double-end screw type.

To continue to recount the varied character of work performed at these works

would be an almost endless repetition of what has been enumerated and a summary of all the various kinds of mechanisms which have contributed to the advance in progress of the country at large.

Let me, however, in the words of Mr. Thos. J. Rider, give an account of some of the occurrences which happened in the early eighties after I left there just to furnish an insight into the character of the man Cornelius H. DeLamater himself, and to indicate what the men thought of him and would do for him.

"The year 1888 was an eventful one, the winter was very severe and I had plenty of trouble with the janitors letting their pumping engines freeze and burst. Then when we all felt we were through with it the blizzard came and snowed us all up. Several of us were in Mr. DeLamater's office when Charley Capes, the paymaster, came in to ask what he would do about paying off. He could not get to the bank and didn't think anyone would be in if he could get there. Mr. DeLamater spoke up and said he had been in business nearly fifty years and in all that time he had never missed paying his men on Monday but once before, during the Civil War, when the clerk who was sent for the money ran away with it and it was too late before they found out what had happened to do anything about it that day. He told us how the fellow was caught soon afterwards and most of the money recovered, and how he promised that if he would enlist in the army he would be allowed to go. Mr. DeLamater told Charley to pay anyone who came to the window that night if it took every cent in the place, not only in the safe, but all that we in the office had in our clothes and he would reimburse us, but no one came in, for the men who were there in the morning had all gone home long before.

"In April a very disastrous fire happened about 9 o'clock in the evening. We lost nearly all of our patterns and the Ericsson Pumpers that we had in stock for the summer business; in fact the pattern shop and machine shop on the north side of 13th Street, together with the pattern loft and storage room, were all destroyed. As usually happens, the city had been doing something to the water pipes in the street and the water was shut off. Maybe we did not have to hustle that summer! Well, we filled all our orders, but I did not get a full night's sleep till the first of November after our rush was over. We were building at the time of the fire a lot of steam stokers which were on the ground floor of the damaged shop, and the most excited man around was the man for whom they were being made, who had quite a lot to say and was wild for a while.

"However, they were hauled out as soon as possible and found to be in fairly good condition and were finished and shipped without much loss of time.

"The Knights of Labor were strong in those days and gave us some trouble. We had several strikes and during one of them we were building some large ice machines for a brewery on Staten Island. It was a time contract and was well along and the time was getting short.

"One morning one of the foreman spoke to me and said that they had been talking it over among themselves and that there were fourteen men, foremen and

assistant foremen who could take hold and finish them if I would be boss of the gang, in order to help Mr. DeLamater out. He asked me to speak to Mr. DeLamater about it, which I did. After a few minutes consideration, Mr. DeLamater told me to thank the men for him and give him their names, but that if the machines were finished during the strike the brewery would be boycotted and therefore it wouldn't do. However, it would give him a chance to get an extension of time. He mentioned it to me several times afterwards and was very grateful for the offer.

"Just to show what we could do when the need came, I will cite an instance.

"An English steamer arrived with its low-pressure piston broken; it was, I think, 100 or 110 inches in diameter. She was scheduled to sail on the return voyage in just a week; the DeLamater Iron Works was called up and the situation explained. After estimating carefully, we promised to make a new piston and have it in place so that the vessel could sail on time. This was cabled to the other side and the answer came back that it was impossible; no one could make so large a piston in that time that would be safe. The agent of the line was authorized to secure another boat to take her place. We assured him, however, that we could do the job and he told us to go ahead. We made the necessary patterns and cast it in the time we had calculated and it was on the boring mill by Friday afternoon. The little Irishman who ran the boring mill kept it going till Monday morning, when his job was done, and he said he was going home to get some sleep. It was hot weather and with the fine cast-iron dust and his perspiration he was as black as the ace of spades. Another gang took hold then, fitted the piston rings and plugged the core holes. At 5 p.m., Monday, it was on its way to the ship. About 5 a.m., Tuesday, sailing day, it was in place and the cylinder head screwed down all ready for steam. She arrived on the other side without trouble, but the owners said that the piston was made too quickly, that it was taken out of the sand too soon and would break from internal strains. They had another made in the meantime with over two weeks to do it in. They removed our piston and put in theirs, but they took the precaution to carry ours in the hold for a spare, which was lucky, as it turned out, for on her return trip the new one broke and they put in ours at sea and came right along."

I could continue to give further personal reminiscences and more accounts of remarkable work performed at these works, but what I have recounted will have to suffice as giving a fair idea of what they accomplished and what they stood for in the world and in their time.

Mr. DeLamater died of pneumonia after two days' illness, on February 7, 1889, in his sixty-seventh year, and impressive ceremonies were held on Sunday, February 10, at two o'clock at the Church of the Divine Paternity, then at Fifth Avenue and 45th Street, and the Rev. J. M. Pullman of Lynn, Massachusetts, who had been Mr. DeLamater's pastor when he was in New York, delivered a beautiful eulogy, listened to by hundreds of his old and faithful employees. The choir sang the hymns, "Nearer, My God, to Thee" and "O, Ye Disconsolate."

The pall-bearers were Chas. L. Southmayd, Wm. H. Fletcher, Chas. H. Mallory, Elihu Spicer, Samuel H. Seaman, Frederick Weed, John Dewsnap, Wm. Hogg and Myers Coryell. The chancel was filled with flowers sent by his many friends and organizations to which he belonged, including the Union League Club and the Society of Mechanics and Tradesmen, to both of which he had been a devoted adherent. On the casket rested a cluster of delicate roses, a tribute from Captain Ericsson. He was laid to rest in Woodlawn Cemetery, a special train carrying over five hundred of the men who wished to accompany the body to the grave.

Cornelius Henry DeLamater was born in Rhinebeck Heights, Duchess County, N. Y., on August 30, 1821. His parents, William and Eliza Douglass DeLamater, moved to New York City when he was 3 years old. They had very little means and after a common school education the boy started out to earn his own living as chore boy in the hardware store of Swords & Company at the age of fourteen. At twenty he left to join his father in the newly established Phoenix Foundry, which he soon bought, and his subsequent career has been told in these pages.

I quote a few excerpts from the address of Rev. J. M. Pullman at Mr. DeLamater's funeral which I have edited so as to make them read with some continuity of sequence.

"Let me carry your minds back to the time when Mr. DeLamater had been in business in this city for about twenty years. Some of you can remember the financial depression which occurred at the time I refer to. I need not specify particulars regarding his own condition, but he found his promising business career embarrassed, and it looked as though the business structure that for so many years he had been building up was in danger of falling—must fall. But there was another structure, his reputation, that he had been building up among his fellow business men during all those years that was to be tested. What did he do? He went around to the men to whom he owed money, his creditors; he showed them the condition of his affairs; he practically placed himself in their hands. He said, 'This is what I have; that is what I owe; these are the conditions of my business. You know my character. I believe that I can bring the business through the crisis with your help so that none of you shall lose anything.' Now, he had been building up a business that was represented visibly to the eye, but he had been building up a character that was, in the estimation of those men, just as substantial, and that turned the scale of his fortune, and they consented to any arrangement that he thought fit to make. He made the arrangement and in a short time he restored his business to a paying basis. He continued meanwhile to shelter his family in a rented house, and before he bought himself the house at 424 West 20th Street, in which he spent the last years of his life, he gave a dinner to his creditors, and when they sat down at the table every man found under his plate a check covering not only the principal but the interest on what was owed him. That incident tells its own story. Not an extraordinary story, you may say. No, thank God, no. It is not at all without its parallel. But that shows the kind of man Mr. DeLamater was.

"From the time he first entered business as a boy he had the faculty of putting himself in the place of the man he was dealing with. He possessed the rare gift of intuition. He could understand the mentality and point of view of the other man. He was a just man, therefore, because he never considered his personal interests alone without considering the other man's interests at the same time, even if he were the humblest man in his employ. He did as he would be done by in each instance or he tried to, at all events, as much as one busy man can with as large a force of employees as he had, and the men knew that he was honest and fair. They also knew that he was a kind, loving man. The testimony never will be gathered here, never written in any book, but it lies deep in the hearts of his men, so that somewhere in this great universe it is all stored up, his great kindness to his men, his sympathy for them in sorrow or affliction at home, to those who were in financial distress or any other trouble. He had a heart that could feel for men who were weighed down by sin, yes, and by crime, and he knew how to mingle mercy with justice; and that is the reason the DeLamater Iron Works were not burned up in the riots of 1863.

"He was not demonstrative, but he was positive, and when he said a thing he meant it. He was a broad-minded man. Ardent, capable and successful; a lover of literature, of art, capable of various lines of abstruse thought, and a student of philosophy. He was a devout worshipper at the shrine of nature. At his beautiful summer home, Beacon Farm, of some 1,250 acres near Northport, Long Island, he had some of the finest blooded cattle in America.

"Let me tell you an occurrence that happened to me there about ten or twelve years ago. He took me with him one evening down to his home and a party of us went out sailing on the bay. After awhile the wind fell with the setting sun, and a little steamer came out to take us ashore and then he proposed that we, he and I, as the night was going to be fine and as there was to be a moon, should stay in the sailboat and drift in with the tide. Those of you who appreciate a full moon at sea will understand the beauty of the situation as the night drew on. The moon rose higher and higher in the sky and drew the tide up farther and farther in the bays. Silently, noiselessly, every little crevice, creek and indentation was filled. The tide rose, without a sound or ripple, and took the boat in which we sat, by almost imperceptible degrees, towards the land. This was a matter of three or four hours, and we had been busy talking of the future and of what would be the hereafter, and then came one of those periods when a man wishes to be silent and to think things over. We were silent perhaps for an hour, drifting in, little by little. There was the moon in the heaven; here were the waters; here was the land; here was the little boat; here were we. Finally his deep voice broke the silence: 'Mr. Pullman,' said he, 'what is your strongest proof of the existence of God?' I said, 'My own existence. I cannot account for myself, nor for you, nor for any of us with our wonderful organism and the equally wonderful world about us, all fitted together in one infinitely great machine working harmoniously from the infinite past through all eternity. Look at it,' said I; 'we have been sitting here 10 or 12 feet apart for an hour, as much

alone as if there were no other creature in the universe, you thinking your thoughts and I thinking mine. The universe has given us our wonderful physical and mental development. I know by the nature of my own wonderful personality that I was not an accident but the result of the design of an omniscient and omnipotent God.' Then silence came again. There was the landing stake, and slowly we swept toward it. Finally he said slowly, 'Well, I don't see any way of avoiding your conclusion.' And so our evening ended. But the memory of that moonlight night, the memory of his composed, thoughtful face, the memory of his simple, straightforward words, will, I hope, remain with me so long as I have in this or any other world the sense of memory left."

By the articles of copartnership, it was agreed that the works should be continued for six months by the surviving partner after the decease of his associate, and under this stipulation they were conducted by his son, William DeLamater, till 1890, when they were closed down and Mr. DeLamater willed his interest to his widow. He had five daughters and one son. Laura married Mr. Leander A. Bevin, who was in the machinery business in New York City and acted as one of the executors of the estate. Sarah married Mr. Geo. H. Robinson, who became Mr. DeLamater's partner and continued so till 1887, when other interests required his whole attention. Lidie married Mr. John N. Robins, who became associated with the Albany Street Iron Works and later formed the J. N. Robins Ship & Dry Dock Company in the Erie Basin, which he developed till it became a great and paying institution. Zillah married Mr. George Moore, a lawyer of Detroit, Michigan. Adah married Mr. Charles Vezin, a merchant of New York City.

The son, William DeLamater, as a young man, was connected with the works, having special charge of the derrick and handling the launching of vessels and loading and unloading materials at the wharf. When his father died William DeLamater took his place and remained its head until it was closed down in 1890.

It was in the minds of most men a great calamity and loss to the world that Mr. DaLamater should have died when he did and that the great works which he built up and maintained with so much effort and at times with severe struggle, and which always took such a prominent part in the history of the nation, should have ended its career simultaneously.

But the first was the will of the Almighty and the second was the wish of the owners, and the world has to abide by both.

Many of the older workmen went out into the world and, although late in life, started careers which became noteworthy.

Captain Ericsson did not survive the loss of his closest friend. He died on March 8, one month later almost to a day, at the age of 85 years, 7 months and 7 days. With one accord the nation mourned the loss of a man whom scarcely anyone knew or had ever seen. But the world acclaimed his genius and desired to pay tribute to it. On Monday, March 12th, his house at 36 Beach Street was thrown open early in the morning and for several hours a human stream of thousands viewed the re-

mains of him of whom they had read and heard so much but had never seen. At noon the casket was closed and, accompanied by the pall-bearers and a procession of some 500 delegates from the DeLamater Iron Works and other organizations which desired to pay their respects to his memory, the body was removed to Trinity Church.

Leading the procession to the church were the Swedish Consul Börs and Vice-Consul Raven, Commodore Joseph Tooker representing the Navy, Mr. Charles E. Emery representing The American Society of Civil Engineers, Dr. C. W. Torry the American Society of Mechanical Engineers, and Mr. John N. Robins representing the DeLamater family.

Following these came Captain Ericsson's superintending engineer, Mr. V. F. Lassoe, his private secretary, Mr. S. W. Taylor, and his executors, Messrs. George H. Robinson, C. S. Bushnell, Edw. Sprout and W. H. Wallace.

The pall-bearers were Wm. DeLamater, L. A. Bevin, Dr. T. M. Marcoe, Dr. Joshua C. Boulee, Prof. R. Ogden Doremus, Chief Engineer C. H. Haswell, U.S.N., Chief Engineer C. H. Loring, Chief Engineer W. W. Duncan, U. S. N., Chief Engineer David Smith, U. S. N., Alexander Pollock, Thos F. Rowland, John O. Sargent, Col. Robert G. Ingersoll, George T. Van Wagenen, H. T. Brown, John P. Kelly, Prof. C. W. MacCord, Col. Wm. C. Church, John L. Haskell, Jas. A. Robinson, Geo. E. Pond, John K. Haskins. The Episcopal service was rendered, Rev. Morgan Dix and the staff of the church officiating. The choir sang the hymns, "Lead, Kindly Light" and "I Heard a Voice from Heaven."

After the ceremonies the casket was removed to the marble receiving vault in Second Street between First and Second Avenues to await the formal arrangements of the Swedish Government, which had requested permission to have the body transported to Sweden for burial.

The Swedish Technical Societies and the Swedish Glee Club accompanied the body and placed it in the vault with appropriate ceremonies.

It was not until August 23, 1890, that arrangements were completed between the Swedish and United States governments for the removal of Captain Ericsson's remains to his native land. New York City made that day notable. The New York *Times* of the following day devoted nearly a full page to its account of the occasion. Excerpts from its columns read:—

"This city was the scene yesterday of one of the most remarkable tributes ever paid by a people to the memory of a great man. It was the day appointed for the removal of the remains of Capt. John Ericsson from this country which he loved so well and for which he did so much, to the land of his birth, where he was held in as high esteem as here. The city was decorated with bunting and the shipping along the water fronts of New York, Brooklyn and Jersey City was dressed in colors, regardless of the nationality. Vessels in the harbor vied with them.

"The event must stand as unique in the records of public ceremonials in the city. Such general decoration and so large a concourse of people had never been

seen here in honor of the memory of one man except when the hero of Appomattox was carried to his last resting place, and the exhibit of sentiment was all the more remarkable in that it seemed to represent an awakened appreciation of the qualities of a man so retiring and unobtrusive in his personality that to the mass of the citizens who turned out to do him homage he was an entire stranger.

"But if in his long lifetime he had been a popular hero the tribute of the people could not have been more earnest or devoted. The start of his journey homeward was all that a hero's could have been.

"From the hour that the city awoke to find itself arrayed for the occasion until the fleet of warships had given the parting salutes to the ship to which Sweden's precious freight was consigned, it was Ericsson's day in New York.

"The ceremonies were begun in the Brooklyn Navy Yard in the early morning when the battalion of marines and squad of bluecoats who were to serve as actual pall-bearers were assembled and marched on board the government tugs Catalpa and the George Starr. These boats drew up at the pier at East 3rd Street at 11.15. The men landed and marched through 3rd Street to First Avenue, thence to 2nd Street between First and Second Avenues facing the Marble Cemetery, where the remains of Captain Ericsson had rested for a year in an underground vault.

"Two flags, one the Swedish emblem and the other the flag that floated over the original Monitor, loaned by Mrs. John A. Griswold of Troy, were interwoven in a handsome wreath of oak leaves and laid upon the casket.

"The Swedish singing societies, who had gathered to the number of seventy-five, sang the 'Battle Prayer.' The procession, composed of the mayor of the city, Secretary of the Navy and many naval officers, formed in line and followed the Marine Band, which played 'Nearer, My God, to Thee.'

"The route was through 2nd Street to Second Avenue to St. Marks Place to 8th Street to Astor Place to Broadway and thence to the Battery. On either side of the catafalque marched the following survivors of the Monitor:—Captain Louis N. Stodder, who was acting master; Patrick Hannon who was 1st class seaman; Hans Anderson, who was a sailor; Geo. S. Geer, fireman; Wm. H. Nichols (colored), wardroom steward; Daniel Toffey, clerk.

"The following were some of the organizations in the line of procession:—Knights of Temperance, Odd Fellows, Grand Army of the Republic, DeLamater Iron Works, Swedish Engineering Societies, American Society of Civil Engineers, American Society of Mechanical Engineers, several posts of the Naval Veteran's Association, several temperance societies and many others.

"The pall-bearers were sailors from the monitors in the bay, the Nantucket, Kearsarge, Petrel, Pensacola, Enterprise, Atlanta, Yorktown, Patapsco, Nahant, Montauk, Passaic and Catskill.

"The casket was placed on the government tug Nina and accompanied by Captain Tracy, Mayor Grant, Admiral Worden, Rear Admirals Gherardi, Walker and McCann, Geo. H. Robinson, Baron Beck Frue, Count C. Levenhaupt, Col. W. C. Church, O. S. Bushnell, V. F. Lassoe, and Samuel W. Taylor. The Nina steamed

out to the Baltimore, the most modern U. S. cruiser, where Captain Schley in charge waited to receive the remains.

"When the remains with the accompanying party came on board the cruiser Baltimore, Mr. George H. Robinson, speaking for the U. S. Government, addressed Captain Schley in part as follows:

" 'Captain Schley, in the nation's tribute to our illustrious dead the simple duty falls to us to yield to the claims of his mother country, that she may again receive her son. We send him back crowned with honor, proud of the life of fifty years he devoted to this nation, and with gratitude for the gifts he gave us.

" 'Was he a dreamer? Yes. He dreamed of the practical application of screw propulsion, and the commerce of the world was revolutionized. He dreamed of making naval warfare more terrible, and the Monitor was built. Again he dreamed, and the Destroyer with its submarine gun was born. He dreamed of the possibilities of obtaining power from air at high temperatures, and behold ten thousand caloric engines. He dreamed of the sun's rays in sandy deserts where water was hard to get, and the solar engine came; and so he dreamed and worked for seventy years.

" 'To you, Captain Schley, we commit these remains. An honorable duty is yours, to deliver them to his native country. We shall keep his memory here.'

"After the closing exercises, the party returned to the shore and the cruiser Baltimore weighed anchor and steamed down the bay, passing the Statue of Liberty, the emblem of that human possession for the preservation of which Captain Ericsson had devoted his great genius. As the cruiser passed through the ranks of the Monitors and other men-of-war, their guns and those of the forts at the mouth of the harbor thundered a salute and on land the church bells tolled a last farewell. Then the Baltimore proceeded with its Swedish convoy of battleships to the home port of Gothenburg, which was waiting to greet its arrival by a great naval display."

So fell the curtain on the last act in a great drama staged in a national theater, the DeLamater Iron Works, a glorious ending befitting the career of one of the two characters who built up an institution which served its country loyally in war as well as in peace for half a century.

Then as if a relentless nemesis was awaiting an opportunity to obliterate the last vestige of the existence of the works, the city bought its West Side water front and cut a broad marginal way through it with modern piers facing on it, to accommodate its shipping, and now the waters of the Hudson River flow over and past the site of the works and its name is no longer even a memory in the locality.

A life-size statue of Captain Ericsson, with the model of the Monitor in his hand, stands at the battery. A life-size statue of Cornelius H. DeLamater should be erected in front of the 14th Street Ferry-house which adjoins the old site of the DeLamater Iron Works and a bronze tablet recording the combined work of both these men should be placed on the front of the Cunard pier to mark the site itself.

It was a fortunate circumstance that brought Cornelius H. DeLamater and Capt. John Ericsson together early in life and provided the facilities which the DeLamater Iron Works offered for the cooperation of these men in the fields in

which they were respectively great. Without Ericsson the DeLamater Iron Works might not have reached the distinction they achieved. Without the DeLamater Iron Works and the opportunity offered to experiment in them freely which Mr. DeLamater extended, Captain Ericsson's genius might never have developed to its full expression. Each supported the other in the drama which they played together for fifty years, and the world appreciated their accomplishment and realized their loss and at the end acknowledged its obligation to both.

We who remain of those that worked on that stage will cherish our connection with it and as long as we live will endeavor to keep alive the associations which we enjoyed there during a very important portion of our lives.

After several years had passed some of the men who had worked in the DeLamater Iron Works, desirous not only of perpetuating the memory of the great institution in which they had spent their best days but of keeping up the friendships which they had formed during that time, decided in 1905 to form an organization which they termed "The Associated Veterans of the DeLamater Iron Works." The appropriate insignia of the Association is a propeller wheel and the color of the sustaining ribbon red, and at every meeting a souvenir bearing them is presented to the guests. The meetings have been held annually with a banquet in February, the anniversary of Mr. DeLamater's death, and those invited to attend it had associations with the works or with some of the other works intimately related to it.

These gatherings have been large and notable. At the first dinner, which was held at the New York Athletic Club, Mr. Alexander Miller was elected president, Mr. James V. Ireland, secretary, and Mr. Walter M. Parker, who was the originator of the idea and has been its inspiration ever since, its treasurer.

A magnum of champagne was purchased, and on the metal covering of its neck each original member scratched his name and it was arranged that this bottle be held in sequence annually by the president of the Association until the last original member alone remains, when he shall open it at the annual dinner and its contents shall be drunk to the memory of those who have preceded him.

Whether the draft of its contents will hasten their departure is a question, for on January 9, 1912, the Equitable Building at 120 Broadway burned down and the box holding the bottle, which was in the custody of the then president of the Association and was kept in the safety vault in the basement, passed through the fire and was both scorched by it and afterwards frozen in the ice formed by the water from the fire engines. How extreme heat and extreme cold affect champagne in a closed bottle remains to be determined, but at all events the bottle is now an interesting souvenir and at every annual dinner it stands on the table before the president. In the course of the dinner just before the coffee comes on, the lights are lowered and the president asks all to rise and drink a silent toast to the memory of Mr. DeLamater and the men of the works who have joined him in the "Great Beyond" and then the quartette sings softly one of the hymns he loved so well and which he requested should be sung at his funeral, "Nearer, My God, to Thee" or "Abide

with Me," and if ever man can hear the swish of angel wings or feel the presence of the departed he should do so during that solemn moment.

The members of the Association are as follows:—

Veterans.—Joseph E. Aue, Leander A. Bevin, Walter E. Clarke, James Craig, Alexander Cruckshank, Frank Creelmann, H. E. Cornell, O. R. DeLamater, M. Fogarty, F. A. Halsey, Fredk. Hulberg, James V. Ireland, Daniel M. Junk, Alex. A. Kennedy, Arthur J. McGarvey, John A. Moran, Daniel E. Moran, Walter M. Parker, H. F. J. Porter, Wm. Prellwitz, T. J. Ryder, Hugo B. Roelker, R. P. C. Sanderson, John Shields.

Associate Veterans.—W. J. Davidson, Joseph F. Moran, Geo. J. Robinson, Wm. H. Todd.

Associates.—Victor D. Bevin, Sidney Bevin, David A. Byron, B. Frank Crane, Lyman J. Fisher, Hobson Holliday, Geo. S. Humphrey, Chas. P. Kennedy, Andrew Murray, Jos. W. Richardson, Norman A. Robertson, Jos. H. Turl, Harry Wheeler, John O. Williams.

In Memoriam.—C. C. Capes, Wm. A. McNab, Alex. Miller, Wm. S. Miller, A. H. Raynal, Geo. H. Reynolds, W. D. Stivers, Chas. Van Wagenen.

NOTE:—For much of the information contained in this paper I am indebted largely to Mr. Ogden Mills, Mr. L. A. Bevin, Mr. Geo. H. Robinson, Mr. Hugo B. Roelker, Mr. Thomas J. Rider, and Mr. Irving H. Reynolds, to whom I desire to express my appreciation for the trouble to which they went to give it to me.

For illustrations relative to this paper see Plates I to II.

DISCUSSION.

THE PRESIDENT:—I sincerely hope nobody will call me a poet after the reading of that doggerel. I had forgotten all about the matter until Mr. Porter referred to it. Fortunately it is not in his paper. It is quite my custom, while something is going on at meetings, to jot down a few notes. The "Old Oaken Bucket" came into my mind on the occasion mentioned by Mr. Porter, and I paraphrased the lines of the well-known poem, applying same to the DeLamater Iron Works, without any idea that anyone would ever again hear of them.

I can truly say that the DeLamater Iron Works was a great institution, and though I was never officially connected with it in any way (for I was connected with a much smaller concern, the old Fletcher-Harrison & Co. North River Iron Works), yet I can truly say that my association with Mr. DeLamater and Mr. Robinson, and all of the gentlemen that Mr. Porter has named, remains in my memory as a very pleasant one. Mr. DeLamater, great man that he was, was very democratic. When I was a young man, running up there frequently to look after work being done for my employers, he always greeted me as though I was really of some consequence. It was due to Mr. DeLamater that Mr. William H.

Webb asked me thirty or more years ago to become one of the charter members of Webb's Academy and Home for Shipbuilders. I have had the honor of being connected with that institution ever since, and I also have the great satisfaction of knowing what great good that institution has done for this country in educating naval architects and marine engineers. So these reminiscences bring back very pleasant memories.

Is there anyone who desires to say anything about this paper?

Rear Admiral Francis T. Bowles, *Past President:*—I have always taken an interest in historical matters affecting the Navy and its development. I very much appreciate the pains and time that have been taken by Mr. Porter to set down the records of the DeLamater Iron Works, because I feel that the DeLamater Iron Works was the most prolific agency in the development of inventions and enterprises which have gone, not only to build up the Navy of the United States, but have, in many respects, formed the foundation on which the modern navies of the world have been built.

It is possible that a careful examination of this paper may bring about some discussion of the facts stated, but that is inappropriate to this moment. I feel, however, Mr. President, that the thanks of the Society are due to Mr. Porter, and I am sure that the facts he has set forth will be of benefit to this Society for all time. I move a formal vote of thanks of the Society to Mr. Porter.

Rear Admiral Washington L. Capps, *Vice-President:*—I would like to associate myself with Admiral Bowles in expressing the appreciation of the Society of Mr. Porter's admirable presentation of the historical facts recorded in this paper. Several statements of fact will, undoubtedly, be news to a great many, and other statements of fact which have been recorded are eminently worthy of record. For instance, the fact that civilian employees of the DeLamater Iron Works were actually on board the Monitor on that historic occasion, when warship naval architecture was almost revolutionized, is something that very few people know. These civilian employees went into battle apparently as a part of their day's work, and this notable fact has probably been forgotten by many.

I think we are all under obligations to Mr. Porter for having gone to so much trouble in bringing together the facts and recording them in permanent form, and I will heartily second Admiral Bowles's motion for a vote of thanks.

The President put the motion to vote and it was duly carried.

The President:—Mr. Porter, will you accept the thanks of the Society?

Mr. Porter:—I thank you.

The President:—The next paper on the program is No. 2, entitled, "Revival of Wooden Shipbuilding as a war Industry," by Mr. Carlos De Zafra, M. E., Associate Member.

REVIVAL OF WOODEN SHIPBUILDING AS A WAR INDUSTRY.

By Carlos deZafra, M. E., Associate.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

It is interesting to note that the supremacy of nations has been ever proportional to their command of the seas. Greek history, Egyptian history, Roman and Spanish history are each most exciting during their respective sea power periods. Little difference did it make were the propelling force man power, as exemplified in the 40 and 60-oared galleys of medieval days, or sail or steam as of to-day.

It is also interesting to note that, in the text-books up to shortly before our Civil War, no reference to metal vessels is to be found, because, since iron will not float, the idea of an iron ship was preposterous. Also, its effect on the compass would be fatal; its corrosion in water and fouling from marine growth were arguments against the use of iron. These objections, however, were gradually overcome as the first argument, that of the non-floatability of iron, was found to be based on a fallacy.

Steel seems to have been introduced as a shipbuilding material about 1870, but there is no denying that the wooden vessel has given excellent service and, in the emergency in which we now find ourselves and notwithstanding the tremendous steel output for shipbuilding purposes, the wooden ship which gradually became obsolete has again come into its own.

The allied nations of this great war have been quick to supplement their shipbuilding programs with provision for a number of wooden ships. This has resulted in a revival of an old and obsolete industry to a degree, in this country, far exceeding in magnitude its most glorious days, and this in the face of a war—indeed, in the heat of battle as it were—for it is now that the strength of the United States is being felt in no uncertain degree on the battle front of Europe, and it is our honored Secretary of the Navy who said that the measure of ships was the sole measure of American strength in France to-day.

In connection with the present shipbuilding activities, there has been considerable speculation as to what will be the amount of tonnage produced by the United States during the year 1918. A recent estimate places this amount at 4,000,000 tons deadweight capacity, and I have even heard 6,000,000 tons mentioned in an offhand way. Stupendous events and undertakings are now under way, and the expectations of the allied governments are such as demand tremendous results from us.

Let us retrospect a little, that we may get a better perspective of the whole proposition and better appreciate what we are trying to do, and are doing, to-day.

Going back a few years, when normal conditions prevailed, we find the following condition of the shipbuilding industry:—

Average production of shipyards, throughout the world, for 1909 was only 1,602,057 tons. This represents low tide. In 1913 we find the high tide mark at 3,332,882 tons. Therefore we may take, as a fair average, the five-year period 1910-1914, inclusive, during which the average annual production was 2,740,000 tons gross. Of this amount:—

	Per cent	*Tons*
The United Kingdom launched about	60	1,650,000
Germany launched about	12	333,000
United States coast and Great Lakes (rivers excluded)	9¼	253,000
France	4½	121,000
All other countries, including Canada and British colonies	14	385,000
Total		2,742,000

WORLD'S TONNAGE.

The entire world's merchant tonnage for the year ending June 30, 1915, amounted to 49,262,000 tons, owned as follows:—

	Per cent	*Tons*
United Kingdom	43.5	21,300,000
United States (excluding rivers and small lakes)	12	5,900,000
Germany	10	5,000,000
France (less than)	5	2,300,000

Taking the greatest tonnage of merchant vessels launched by any nation in any one year between 1899 and 1915 inclusive, and combining these, we can arrive at a fair approximation of the then production capacity of the world's shipyards.

These figures give a total capacity of 3,685,000 tons of which—

	Per cent	*Tons*
The United Kingdom and colonies and Canadian Lake ports launched	54	1,984,000
United States coast and Great Lakes	14.6	540,000
Germany	12.4	465,000
All other countries	19	696,000

But do not overlook this point—these latter figures are based on the maximum capacity for each country as developed at different periods, but not actually realized in any one year.

Generally speaking, these were the conditions prior to the introduction of German "reckless and ruthless" submarine warfare, and the figures are reasonably ac-

curate and as presented before this Society by its president, Stevenson Taylor, in his address in 1916.

You will notice from these figures that the estimated capacity of the world's shipyards was 3,685,000 tons. We are told that the United States alone is suddenly expected to produce 6,000,000 tons. Germany required forty years during which to construct its powerful military machine. It has taken the United States one year to build up a shipbuilding machine that is going to whip that military machine to pieces.

Do you realize, gentlemen, what this means? It means that in one year's time the United States is expected to produce approximately 5½ million tons more than its maximum capacity prior to 1915, or, in other words, 2,000,000 more tons are expected of the United States alone than could be produced by all the shipyards of the world combined in 1915.

There is under construction, at the present time, approximately a tonnage aggregating 6,700,000, of which 5,000,000 is steel and 1,700,000 is wood, this being exclusive of naval construction which in itself numbers approximately 794 vessels. Their tonnage of 420,217, however, is in terms of displacement and not of cargo capacity as applied to merchant vessels.

The following tabulation of the world's wooden ships may prove of interest to many:—

World's Wooden Ships.

Recorded in Lloyds—100 Tons or Over.

Year	Power	No.	Tons	Year	Power	No.	Tons
1890....	Steam	902	360,147	1914....	Steam	1,337	408,261
	Sail	18,924	6,693,738		Sail	4,570	1,575,197
Totals	.....	19,826	7,053,885	Totals	.....	5,915	1,983,458
1910....	Steam	1,407	451,584	1915....	Steam	1,332	410,013
	Sail	5,892	2,093,274		Sail	4,445	1,510,251
Totals	.....	7,299	2,544,858	Totals	.....	5,777	1,920,264
1912....	Steam	1,435	451,304	1916...	Steam	1,324	406,241
	Sail	5,180	1,819,254		Sail	4,297	1,449,935
Totals	.....	6,615	2,270,558	Totals	.....	5,621	1,856,176
1913....	Steam	1,378	422,175				
	Sail	4,818	1,691,101				
Totals	.....	6,196	2,113,276				

The following table of construction of wooden ships is of particular interest for comparison with the present day program:—

World's Construction Wooden Vessels.

Year	Power	No.	Tons	Year	Power	No.	Tons
1890....	Steam	60	167,974	1910....	Steam	32	7,389
	Sail	377	20,201		Sail	64	16,348
Totals	.....	437	188.175	Totals	....	96	23,737
1895....	Steam	27	10,312	1912....	Steam	48	15,211
	Sail	120	38,875		Sail	74	23,264
Totals	.....	147	49,187	Totals	.....	122	38,475
1900....	Steam	60	27,208	1913....	Steam	57	15,106
	Sail	212	102,084		Sail	66	23,480
Totals	....	272	129,292	Totals	.....	123	38,586
1905....	Steam	58	18,610				
	Sail	109	36,022				
Totals	.....	167	54,632				

There has been much speculation as to the value of wooden ships to-day—as to whether or not they would last, particularly because constructed of so-called "Green Timber." Gentlemen, the Battle of Lake Erie was won with green timber and what mattered it afterward whether the ships kept or not? The world war to-day will be won with green timber; and after it is won we can replace these ships with steel, if need be, though it is my personal opinion that it will be many decades before the last of the present-day wooden ships has passed away.

The sudden revival of wooden shipbuilding as a war industry has necessitated a revival of old shipyards, their enlargement and modernization. It has meant the return to shipbuilding of many who, through its decadence as an industry, had sought a livelihood in other directions. It has caused the construction of new shipyards from new materials and under the guidance of new minds, and, strange as it may seem at first, some of the most successful of the new enterprises have been under the jurisdiction of the "landlubber," the construction and the civil engineer.

I want to call your attention particularly to two west coast yards, conceded to be the finest yards in the world for the construction of wooden ships. One is at Tacoma and the other at Portland, each constructed to handle one-half of a contract of 40 steam auxiliary wooden schooners of 3,000 tons deadweight each, for the French merchant marine, and awarded to The Foundation Company.

Plate 12 shows the yard site of the Tacoma plant as it appeared in the early part of August, 1917, a 46-acre mud shoal lying from 7 to 12 feet under water between two bulkheads. At low tide the mud flats were clearly seen outside the bulkheads. In order to provide a launching basin and a fitting-out basin, it was

necessary hydraulically to dredge these flats, pumping the "fill" into the area between the bulkheads, with the result shown in Plate 13, which is that of the completed yard, while Plate 14 shows a close view of the grading and keel blocks ready for service only seven weeks after dredging began.

New conditions in industry create new machinery with which to meet those conditions. Shipbuilding is no exception. There are many new developments in woodworking machinery to-day brought about by the call for "Ships, Ships, and Still More Ships," principal among them the new types of bevel band saw, and that very ingenious machine, the bevelling machine, wherewith frames can be shaped with their varying bevels so closely as to require almost no dubbing. The illustrations show some work characteristic of this machine, and among them you will note a set of ships' knees, Plate 15, more perfectly faced on both sides in fifteen minutes than could be done in the old days by one man and an adz in as many hours. These eleven knees were loaded on the carriage, surfaced on one side, turned over, and surfaced on the other side, the complete operation requiring only the time specified—15 minutes.

Plate 16 illustrates a vessel on which, I am advised, hand tools were not used in bevelling the ceiling. Every piece was accurately bevelled on the bevelling machine. Even the back of the ceiling at the turn of the bilge was bevelled by machine.

Plate 17 illustrates the combined bevelling, reverse bevelling, and curving possibilities of this machine. Before photographing this timber a cut was made for a few feet, the bevel starting at 11 degrees to the left, the angle continually changing until finishing at 11 degrees to the right.

The framing having once been cut, the present-day wooden shipyard constructs a temporary "framing platform" at the head of each ways, upon which the frame segments are assembled and fastened. The frame sections, complete from gunwhale to gunwhale, are then slid down the keel and guiding bilge track to their final position.

In this connection your attention is called to the rapid work which was performed in the new Portland, Oregon, yard previously referred to. The accompanying illustrations show the erection of ships' frames for a twelve-day period, Fig. 1, Plate 18, being taken November 2, 1917, and Fig. 2, Plate 18, on November 14, 1917. In the first the framing had only just begun on two ships, and at the end of the twelfth day the entire square framing of five vessels had been completed. During the following twelve days five other vessels had been also square framed on the keels between the vessels shown in the November 14th photograph. A gang on 12-inch ceiling has been handling the job at the rate of 24,000 feet a day.

Some modifications in structure have been brought about under the pressure of necessity. When power was introduced in the first wooden vessels little change in design from the then prevailing sailing vessel was made. To quote Campbell Holmes' "Practical Shipbuilding":—

"They had a flush upper deck, and, in the absence of a second deck, a tier of

hold beams. At the bow they had an anchor deck, or low 'monkey forecastle,' and aft there might be a raised quarter-deck.

"Subsequently it was found necessary to place the machinery openings at a higher level than the upper deck, and so, for this purpose, casings were built, and, to protect these, a bridge deck, enclosed at the ship's side but usually open at the ends. Then, to increase the carrying capacity and improve the vessel's weatherly qualities, the quarter-deck and forecastle were increased in height to form the poop and top-gallant forecastle. The largest vessels of that period were about 250 feet by 33 feet by 17½ feet, but later, when greater carrying capacity was desired, they were increased in size by simply adding 7 feet to their height, so as to give an additional deck. To increase the depth only was thought to be advantageous, for at that time the idea prevailed that the dimension of breadth was the one most particularly governing the vessel's resistance, and that to increase it would entail great loss of speed."

To-day's problems have introduced some new details of construction. On the Pacific coast long timber is available, keel sticks being from 80 to 100 feet and in a few instances, I am told, as long as 150 feet between scarphs, while on the Atlantic coast a 50-foot length would be considered a good specimen. On both coasts, however, steel has been introduced for keelsons and for brackets or braces to supplant the ever-decreasing supply of ships' knees.

Plate 19 shows a view in a 250-foot 2,500-ton wooden steamer wherein the steel keelson is being assembled in place.

The use of iron strapping on wooden vessels necessitates rabbeting the frames so that the frame and strapping surfaces will present a smooth face on which to lay the planking. To expedite this work, a portable pneumatic rabbeting tool has recently been developed and used with excellent results.

Painting by the old hand and brush method was laborious, time-consuming and ever wasteful. The use of compressed air has solved these difficulties to a great degree.

In the launching of vessels there is always the usual interest of watching a large mass slide gracefully down the ways to repose in its element. To-day, however, the interest is held in another direction coincident with the launching, namely, the keel laying of the next ship to be built on the same ways. On the west coast we prided ourselves when a new keel was laid in 20 minutes after the launching. Later we beat it at 16 minutes, later at 11 minutes, and finally got it down to one minute, a world's record. In the old days many weeks would elapse before a new set of keel blocks was ready and the new sticks were scarphed and ready for assembling and fastening. Now, thanks to the introduction of quantity production and fabrication methods to wooden ship production, we can use the same keel blocks without disturbing them at launching and, by having the new keel all in readiness under the bilges, it can be hauled to place on the vacated keel blocks as rapidly as the sister ship glides to her maiden plunge. This is shown in Plate 20.

In the matter of fitting out vessels, records have been made. The vessels which

I have referred to principally—the 3,000 ton auxiliary schooners—are of the five-masted bald-headed type designed by Messrs. Cox & Stevens of New York. They are fitted with two triple-expansion steam engines and two water tube boilers, and have given an average of about 10.5 knots on trials. There has been developed a gang of nine riggers at one of these yards, which is turning out "one complete equipment of standing rigging in about five days" and they challenge all comers to equal or better their record. Plate 21 gives an idea of what this means.

The work above mentioned is that of a new enterprise manned by men new in the business, though under the leadership of some of the most capable and experienced shipbuilders to guide them, and therefore deserving of every credit for turning out forty ships of the 3,000-ton class—a total of 120,000 tons deadweight—within fourteen months from the laying of the first keel, as per present indications, an average of "one every seven days." Details of these vessels, which would be of much interest to the members, must of necessity be omitted for the present, as the contract under which they are being built has not as yet been completed. Plate 22 shows the general appearance of the completed vessel.

DISCUSSION.

The President:—We will now proceed to paper No. 3, entitled "Application of Buoyancy Boxes to the S. S. Lucia for the United States Shipping Board," by Mr. W. T. Donnelly, Member. The copies of paper No. 3 have not arrived in sufficient number to be distributed to the members, but Mr. Donnelly has several copies, and he will be glad to furnish any one with a copy who desires it.

Mr. Donnelly read the paper in abstract, and, in connection therewith, he said:—

"With regard to the application of these buoyancy boxes, if a ship is loaded with a cargo of coal, almost a third of the space available in the hold will be found left above the coal. This does not help to carry the coal, and if you put more coal in you will sink the ship. The space above the coal does allow the water to come in if the ship is punctured and the ship goes to the bottom. If the space is filled with dependable buoyancy boxes, the ship will not go to the bottom. If the cargo is one of ore, iron or copper ore, it would perhaps not take up more than a third of the space, and the rest of the space would be available for means for preventing the ship from sinking. I will leave the mathematical statement, as the reading of that would be rather dreary and apt to be burdensome."

APPLICATION OF BUOYANCY BOXES TO THE STEAMSHIP LUCIA FOR THE UNITED STATES SHIPPING BOARD.

By W. T. Donnelly, Esq., Member.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

The unprecedented sinking of vessels by submarines in the early part of 1917 directed universal attention to the possibility of protecting ships against the attacks of the submarine.

The result was a tremendous influx of ideas, scientific, practical and impractical, to all the departments in Washington.

It soon became apparent that some organization must be gotten together to handle this mass of material and meet by counter endeavor, if possible, the menace of the submarine.

This resulted in the creation jointly, by the Naval Advisory Board and the United States Shipping Board, of the Ship Protection Committee.

The original members of this committee were Admiral H. H. Rousseau, chairman, appointed by General Goethals as general manager of the Emergency Fleet Corporation; A. M. Hunt, a member of the Naval Advisory Board to represent that board on the committee; and the writer, who was recommended by the chairman of the Naval Advisory Board, W. L. Saunders.

The preliminary work of the committee consisted of classifying and considering several thousand suggestions dealing with many real, and more imaginary, methods of overcoming the submarine.

The method of rendering a ship safe against sinking by internal buoyancy boxes was the outcome of the writer's experience in the construction of floating dry docks, and this experience has been embodied in United States Patent, dated April 17, 1917.

The idea first took shape before the committee in a copy of this patent submitted from the Patent Office by a clerk of that department.

Fundamentally there is nothing at all new in providing internal buoyancy for ships or boats. On reference to the "General Rules and Regulations Prescribed by the Board of Supervising Inspectors" of the Department of Commerce, United States Government, there will be seen, referring to lifeboats, on page 78, paragraph 17:—

"The internal buoyancy of a wooden boat of this type shall be provided by watertight air cases, the total volume of which is at least equal to 7½ per cent of the cubic capacity of the boat."

A further paragraph reads as follows:—

"The buoyancy of a metal boat shall be not less than that required above for a wooden boat of the same cubic capacity, the volume of the air cases and external buoyancy being increased accordingly."

The discussion of the application of internal buoyancy boxes before the committee and Naval Advisory Board found a unanimous opinion that something along these lines should be undertaken immediately.

The writer, on behalf of the committee, prepared preliminary plans and calculations and investigated the vessels available. This resulted in the selection of the former Austrian steamship Lucia of the following general dimensions and tonnage:—Length, 418 feet; beam, 54 feet; depth, 37 feet; gross register, 6,744 tons; net register, 4,386 tons; coal bunker capacity, 620 tons; water ballast, 1,583 tons; dead weight capacity all told, 9,600 tons; summer draught, 28 feet 11½ inches.

The Lucia was a modern steel freighter, built in Trieste, Austria, in 1912 and equipped with English machinery.

At about the time referred to, the early part of 1917, the shortage of coal in the Mediterranean had reached such a degree that $100.00 a ton freight was being offered, without avail, for ships to carry coal to Italy. In view of this, it was decided to fit out the Lucia so that she could carry coal when water-logged.

A simple statement of this problem is as follows:—

Weights to be Supported.

		Tons.
Weight of coal		8,200
Coal consumed		600
Net weight of coal		7,600
Weight of ship		4,100
Weight of boxing		1,000
Weight of frame filling		250
Weight of dunnage for cargo boxing		90
		13,040

Displacements or Buoyancy.

		Tons.
Coal displacement (specific gravity 1.36)		5,630
Displacement of fittings of hull		400
Steel and machine displacement		520
Double bottom and peaks		1,600
Propeller tunnel		300
Side boxing, 150 lbs. per foot run	7,860 x 150 lbs.	
Bilge boxing, 200 lbs. per foot run	808 x 200 lbs.	
Deck boxing, 150 lbs. per foot run	4,060 x 150 lbs.	
Deck boxing, 150 lbs. per foot run	4,060 x 150 lbs.	
Deck boxing, 200 lbs. per foot run	4,060 x 200 lbs.	
Bulkhead boxing, 200 lbs. per foot run	5,270 x 200 lbs.	
		1,970

Boxing in machine and engine-room	150
Boxing for cargo	3,000
Frame filling	450
Dunnage for cargo boxing	160
	14,180
Reserve buoyancy	1,140
Average reserve freeboard	33″

From the foregoing it is apparent that a liberal margin of reserve buoyancy can be obtained, at the same time retaining 86 per cent of the ship's former cargo-carrying capacity.

DESCRIPTION OF DRAWINGS.

Plate 23 gives a typical cross-section of the ship and the general arrangement of the boxing located along the sides under the three decks, and on both sides of the transverse bulkheads. This drawing also shows the draught lines under various conditions of loadings.

Plate 24 gives details of the various framing construction and fittings necessary to secure the boxes in place. As far as possible a standard size of lumber has been used throughout the ship for this work.

Plates 25 and 26 give details of the three types of boxes found necessary. The boxes have been so standardized that a uniform size of lumber can be used for all types.

Plate 27 gives a general layout of the ship, showing space occupied by the boxing and space available for coal cargo. This drawing also shows a longitudinal section of the ship, giving the various transverse bulkheads and decks.

From the plan as outlined by the figures and drawings above referred to, it will be perfectly plain to engineers, but the carrying of it out for the first time under war conditions was found to be anything but a simple matter. The only material available immediately for creating the buoyancy boxes was ordinary lumber and galvanized iron, and the quantity of sheet metal required was rather a surprise to local markets.

It was soon found that ordinary methods of construction would not do, and careful experiments were necessary to develop the details of construction for the boxes as set forward in the plan.

A testing plant capable of testing the different sizes and types of boxes to destruction by outside water pressure was created and, as might be expected, had to be completely rebuilt before satisfactory results could be obtained.

After the type of box and entire construction for withstanding pressure had been developed, many difficulties were met with before absolutely watertight results could be obtained, and these results were finally maintained only by testing every box by air pressure and floated in a tank before placing it in the vessel.

Approximately 12,000 boxes divided about equally between buoyancy boxes for ship, or cargo where required.

During the construction of the work, considerable discussion arose as to the possible effect upon the stability of the ship when flooded in different compartments, and the first intention of the committee was to flood the Lucia in dry dock and determine her stability under all conditions of flooding, but, very much to the regret of the author, these tests were not carried out, and the Lucia was loaded and sent to sea without any definite knowledge as to her stability or buoyancy in case of total flooding.

There was also much discussion pro and con as to the sacrifice of cargo space, the claim being advanced that all the room occupied by the buoyancy boxes, both for ship and cargo, was detracting from cargo space. In these discussions no consideration was given to the fact that the Lucia had been fitted out to carry a cargo of coal, and that ample space was left to load the Lucia down to her allowable load line with this cargo, as not until the Lucia was ready to sail was it discovered that no coal was available as a cargo.

A careful analysis of the principles involved will show that the necessary reduction in cargo corresponds to the weight of the buoyancy boxes and has no necessary bearing upon the room they occupy.

In making this statement I am very well aware of the contention that shipowners will make of the persistent demand for more cargo space, but this demand means nothing when applied to a single vessel. If this device were to be applied generally, ships would simply be designed with sufficient interior space to allow for the room occupied by the buoyancy boxes, and this would mean very little, if any, hardship upon the designer, and any reasonable analysis of the economic problem involved in the reduction of the risk will show undoubted advantages.

On her first voyage to France the Lucia was hastily and very improperly loaded, resulting in a comparatively light cargo and much more freeboard than was allowable. On at least two subsequent voyages, when loaded under the direction of the writer, the Lucia went to sea loaded to her Plimsoll line, or greatest allowable draught.

Before the sailing of the Lucia on her first voyage, a Naval Advisory Board was appointed, with Admiral A. G. Winterhalter as chairman, to report on the protection of the Lucia by buoyancy boxes. The report is too lengthy to review in this paper, but can be found, by those interested, in the records of the Ship Protection Committee.

The question of stability was again gone into to some extent, and the opinion expressed that the writer's method of calculating stability was at fault, the statement of the report being as follows:—

"The discrepancy is due chiefly to errors which Mr. Donnelly made in the calculation of the moment of inertia of the damaged water line, and in assuming that the

ship would incline longitudinally about an axis through the midship section instead of about an axis through the center of gravity of the damaged water line."

To meet this contention there is appended to this paper a complete mathematical review by my assistant, Mr. G. C. Engstrand, dealing with the stability calculations involved, with the full conviction that they will meet the critical review of anyone interested.

Paragraph 16 of the Winterhalter report is quoted as follows:—

"The board is of the opinion that a vessel left in a condition such as that resulting from the assumptions made in paragraphs 14 and 15 would be a most critical condition and would, sooner or later, sink. However, assuming that there remains a sufficient number of buoyancy boxes undamaged, as a result of the explosion, to keep the vessel afloat, she would be little better than a water-logged derelict and would constitute a menace to other vessels. Even should she be taken in tow and finally brought to port, she would, by reason of her extreme draught, 41 feet forward, be able to enter comparatively few European or other ports, and her salvage within any reasonable time would be difficult."

This at least would seem to show a very reasonable probability that the Lucia would remain afloat, and it would seem too bad that no consideration whatever was given to the salvage of hull and to cargo under such conditions, it being pointed out that a cargo of coal would not be at all damaged. The final conclusion of the board is as follows:—

"The board is of the opinion that the Lucia installation is not practicable for general adoption under existing conditions by reason of:—(1) The questionable efficiency as a preventive against sinking; (2) the reduction in cargo-carrying capacity, both dead-weight and cubic contents; (3) the length of time required."

From a strictly engineering point of view, to question the possibility of rendering a vessel unsinkable under ordinary conditions by such a method is beyond dispute. It is simply a question of the quantity and strength of the buoyancy boxes used. To question the carrying capacity of the ship when so fitted is to question the simplest form of mathematical statement which can be made.

Finally, in the general question of whether ships shall be made unsinkable at sea or not, the time required to so construct a ship will have no bearing whatever upon the problem. The writer is free to admit that military reasons may properly control any action, commercial or otherwise, during a time of war, but at the same time begs to state that only engineering and economic reasons will finally control the question of rendering ships and cargoes safe against loss at sea.

Buoyancy and Stability Calculations for S. S. Lucia.

BUOYANCY CALCULATIONS.

Estimate of Weights and Displacements.

	Tons.
Weight of coal on board	310
Ballast water on board	400
Weight of ship	4,100
	4,810

Draught of ship, 12′ 0″.

Displacement with assumed block coefficient of 0.65:—

$$\frac{10 \times 0.65 \times 54 \times 400}{35} = 4{,}813 \text{ tons.}$$

Weights.

	Tons.
Weight of coal	8,200
Coal consumed	600
	7,600
Weight of ship	4,100
Weight of boxing	1,000
Weight of frame filling	250
Weight of dunnage for cargo boxing	90
	13,040

Displacements.

		Tons.
Coal displacement (specific gravity 1.35)		5,630
Displacement of fittings of hull		400
Steel and machine displacement		520
Double bottom and peaks		1,600
Propeller tunnel		300
Side boxing, 150 lbs. per foot run	7,860 x 150 lbs.	
Bilge boxing, 200 lbs. per foot run	808 x 200 lbs.	
Deck boxing, 150 lbs. per foot run	4,060 x 150 lbs.	
Deck boxing, 150 lbs. per foot run	4,060 x 150 lbs.	
Deck boxing, 200 lbs. per foot run	4,060 x 200 lbs.	
Bulkhead boxing, 200 lbs. per foot run	5,270 x 200 lbs.	
		1,970
Boxing in machine and engine room		150
Boxing for cargo		3,000
Frame filling		450
Dunnage for cargo boxing		160
		14,180

Reserve buoyancy 1,140
Average reserve freeboard ..... 33″
Stability calculations (Plate 27).

Transverse Stability.

In the following calculations the section modulus of the water plane is taken as 0.7 of the section modulus of the circumscribing rectangle.

It is to be noted that these calculations are approximate, and that their only object is to show that the ship is more stable when bilged than under ordinary conditions. All moments are figured for a heel of 1 foot in 100 feet.

Ship Torpedoed Light. All Compartments Flooded.

Water Plane Moment:—

$$+0.7 \times \frac{53^2 \times 400}{6} \times \frac{1}{35} \times 0.265 = +970 \text{ foot-tons.}$$

Free Ballast Water Moment:—

$$-\frac{30^2 \times 400}{6} \times \frac{1}{35} \times 0.15 = -255 \text{ foot-tons.}$$

Weight Moment:—

$$-6{,}000 \times 0.055 = -330 \text{ foot-tons.}$$

Stability Moment = +385 foot-tons.
Metacentric Height = + 6.4 feet.

Ship Torpedoed Loaded. All Compartments Flooded.

Water Plane Moment:—

$$+0.7 \times \frac{51^2 \times 400}{6} \times \frac{1}{35} \times 0.255 = +884 \text{ foot-tons.}$$

Free Ballast Water Moment:—

$$-0.4 \times \frac{30^2 \times 400}{6} \times \frac{1}{35} \times 0.15 = -102 \text{ foot-tons.}$$

Weight Moment:—

$$-15{,}000 \times 0.01 = -150 \text{ foot-tons.}$$

Stability Moment = + 632 foot-tons.
Metacentric Height = + 4.2 feet.

Longitudinal Stability.

Consider the forward compartments opened by the torpedo explosion. Water will flow into the compartments until the inner and outer water lines coincide. The water in these compartments increases the draught of the ship and also gives it a considerable list.

At Equilibrium.—The average height of water in the forward compartments of the ship in ballast is X feet above the double bottom.

If this amount had been applied at the center of the ship, the draught of the ship would have been:—

$$\frac{37 \times 170}{50 \times 400} \times +13.25 \text{ feet, or}$$

$$37 \times \frac{170}{50 \times 400} \times +9.25 \text{ feet above the double bottom.}$$

If the water load is shifted 108 feet forward, a moment will arise, viz.:—

$$\frac{X \times 37 + 170}{35} \times 108 \text{ foot-tons.}$$

This moment is anti clock-wise.

This moment is counteracted by the water plane moment of the ship. The water plane approximates a rectangle 50 feet $\times$ 400 feet, hence one foot submergence at one end creates a moment—

$$\frac{400^2 \times 50}{6} \times \frac{1}{35} \text{ foot-tons.}$$

$$\left.\begin{array}{l}\text{Section Modulus}\\ \text{of plane around}\end{array}\right\} \Psi \times \left\{\begin{array}{l}\text{Weight in tons of}\\ \text{one cubic foot of water}\end{array}\right.$$

The forward end is submerged a distance—

$$(X = D) \times \frac{200}{108} \text{ feet.}$$

Hence the created moment is:—

$$\frac{400^2 \times 50}{6} \times \frac{1}{35} (X - D) \frac{200}{108} \text{ foot-tons.}$$

This moment is clock-wise.

An anti clock-wise moment of

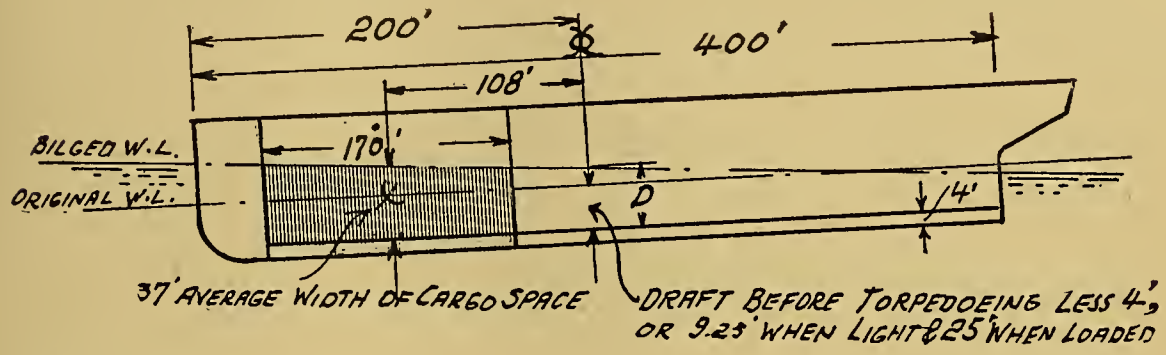
$$\frac{170^2 \times 37}{6} \times \frac{1}{35} \times (X - D) \times \frac{85}{108} \text{ foot-tons}$$

is created by the free water surface inside the ship.

The sum of these three moments will equal zero at equilibrium.

The torpedoing of the boiler and engine-room place will only effect an increased draught as the center line of these compartments coincides with the center line of the ship.

The torpedoing of the aft compartments will only reverse the list as the compartments are of equal size and at equal distances from the center line of the ship, as are the forward compartments.



Ship in Ballast:—

$$9.25 + \frac{37 \times 170}{50 \times 400} X = D = \text{Draught above double bottom.}$$

Moments:—

$$\left.\begin{aligned} &-\frac{X \times 37 + 108}{35} \times 170 \text{ foot-tons.} \\ &+\frac{400^2 \times 50}{6 \times 35} \times (X - D) \times \frac{200}{108} \text{ foot-tons.} \\ &-\frac{170^2 \times 37}{6 \times 35} \times (X - D) \times \frac{85}{108} \text{ foot-tons.} \end{aligned}\right\} \Sigma \text{ Mom.} = 0$$

$X = 23$ feet. $D = 16.5$ feet.

Maximum bending moment equals—

$$\frac{X \times 37 \times 170 \times 108}{35} \times \frac{1}{2} = 220{,}000 \text{ foot-tons.}$$

Ship Loaded:—

0.35 = permeability coefficient.

$$25 + \frac{37 \times 170}{50 \times 400} \times 0.35 X = D$$

Moments:—

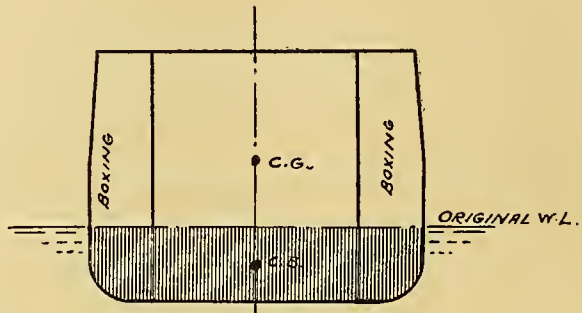
$$\left.\begin{aligned} &-\frac{X \times 37 \times 170 \times 108}{35} \times 0.35 \text{ foot-tons.} \\ &+\frac{400^2 \times 50}{6 \times 35} \times (X - D) \times \frac{200}{108} \text{ foot-tons.} \\ &-\frac{170^2 \times 37}{6 \times 35} \times 0.35 \times (X - D) \times \frac{85}{108} \text{ foot-tons.} \end{aligned}\right\} \Sigma \text{ Mom.} = 0$$

$X = 31$ feet. $D = 28$ feet.

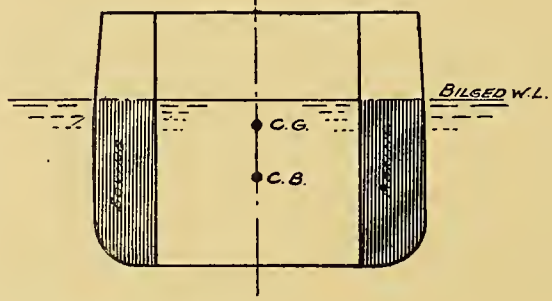
STABILITY CONDITIONS OF S. S. LUCIA AFTER TORPEDOING.

Transverse Stability.

Before attack—



After attack—



Shaded areas indicate displacement.

We see that the center of buoyancy moves up while the center of gravity remains stationary. Stability will of course increase accordingly.

The hasty calculation of the conditions of the Lucia will show that the upsetting moment is reduced approximately 50 per cent while the righting water-plane moment is only reduced approximately 30 per cent.

The ship in bilged condition is therefore much more stable than before.

Longitudinal Stability.

Professor Hovgaard, whose method is used by navy circles, employs the metacentric height method, while in these calculations the section modulus method is used. In other words, the problem is here solved just as we are used to solve the problem of the bending of a beam.

$S \times f = M$ is the well-known bending formula.

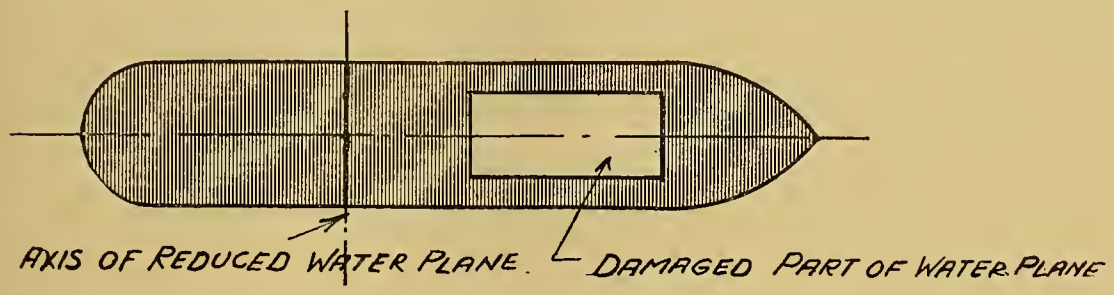
When used in stability problems, S denotes the section modulus of the water plane, f denotes the weight of a column of water of unit section and with a height equal to maximum immersion, M denotes the stability moment.

The metacentric method is really the sequel of the section modulus method and each is readily transferred into the other.

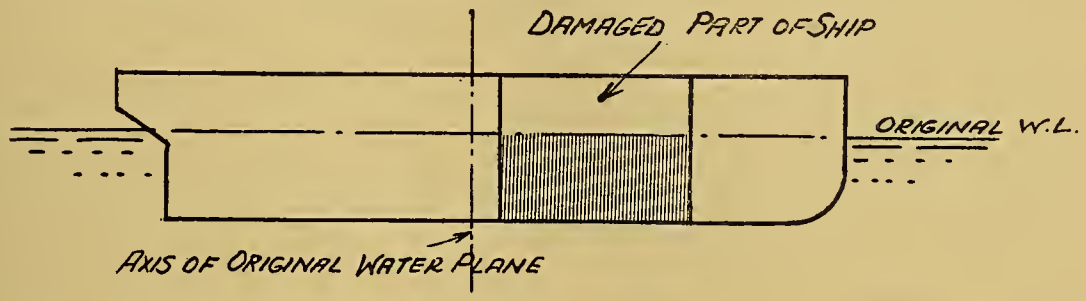
In drydock work and also in ship work where static problems are considered, the mathematical expressions will be vastly simplified by the use of the section modulus method.

There is also another difference between Professor Hovgaard's method of figuring the trim and the method employed here.

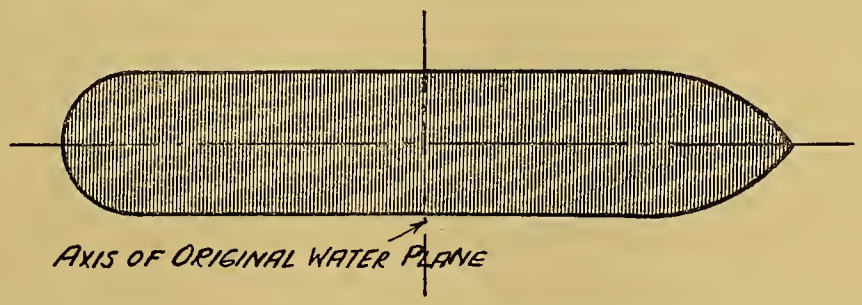
In figuring the maximum trim which will exist when either the entire forward or aft part of the ship is bilged, Professor Hovgaard considers the stability moment of the reduced water plane—



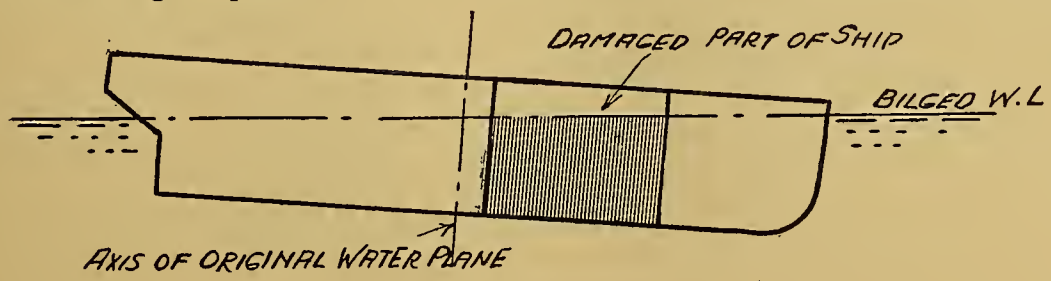
To balance the weight moment of the water up to the original water line around the gravity axis of the original water plane—



In calculations employed in this paper the stability moment of the original water plane is considered—



To balance the weight moment of the total water in the ship around the gravity axis of the original plane—



It is a very simple matter to prove that both methods are identical.

Trim.—Professor Hovgaard's formula in figuring the trim is:—

$$\text{Trim} = \frac{\text{Length of ship} \times \text{weight of water up to original W. L.} \times \text{permeability } \% \times \text{lever around } \Psi \text{ axis}}{G_1 M_1 \times \text{displacement in tons}}$$

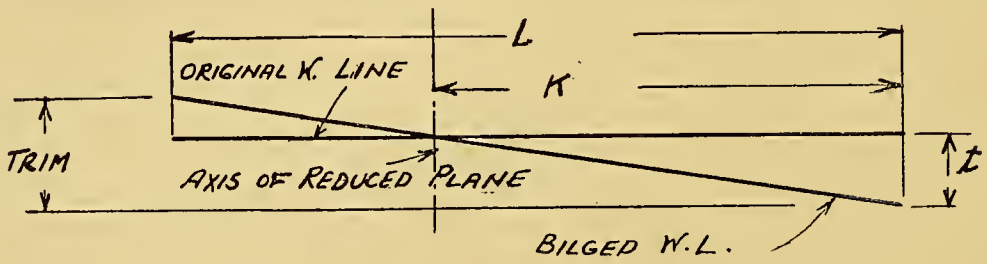
or

$$\frac{\text{Displacements in tons} \times G_1 M_1 \times \text{trim}}{\text{Length of ship}} = \text{Weight moment.}$$

$$G_1 M_1 = B_1 M_1 \text{ when considering longitudinal stability.}$$

$$B_1 M_1 = \frac{I_1}{V} = \frac{S_1 \times K}{V}$$

For denotations see following figure:—

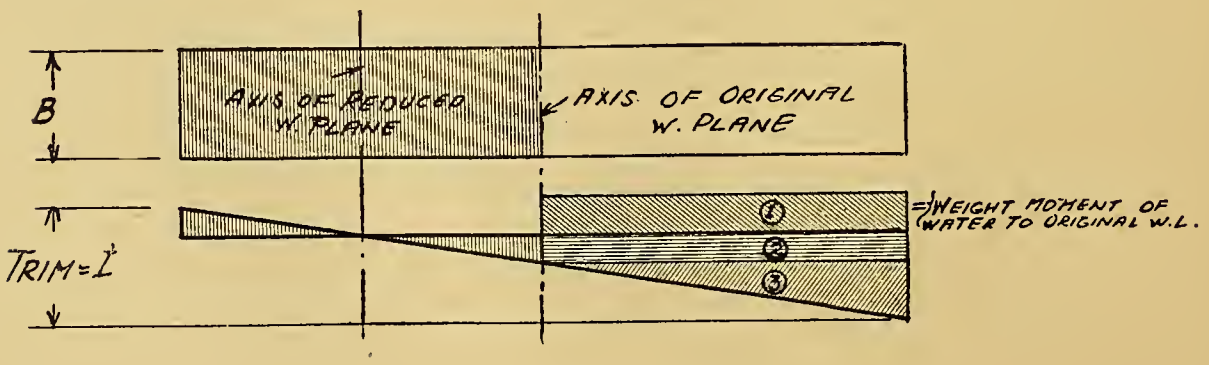


Hence:—

$$\frac{\frac{V}{35} \times \frac{S_1 \times K}{V} \times \text{Trim}}{L} = \frac{S_1 \times t}{35} = \text{Weight moment,}$$

which is the section modulus formulae.

In order to illustrate how the two methods compare we will finally consider that the water plane of the ship is rectangular and has been reduced to half the original length.



Professor Hovgaard's method gives us:—
Section modulus of reduced water plane equals (1) or

$$\frac{B \times \left(\frac{L}{2}\right)^2}{6} \times \frac{t}{4} = M \qquad \text{or} \qquad \frac{1}{96} = \frac{M}{BL^2 t}$$

Method employed by me in this paper gives us:—
Section modulus of original water plane equals ① + ② + ③ or

$$\frac{B \times L^2}{6} \times \frac{t}{2} = M + \frac{L}{2} \times \frac{t}{4} \times B \times \frac{L}{4} + \frac{L}{2} \times B \times \frac{L}{3} \times \frac{t}{2} \times \frac{1}{2}$$

$$\text{or } \frac{1}{12} = \frac{M}{BL^2 t} + \frac{1}{32} + \frac{1}{24} \quad \text{or} \quad \frac{1}{96} = \frac{M}{BL^2 t}$$

Hence same results are arrived at by the two methods.
(1) denotes moment of water to original water line.
① + ② + ③ denotes moment of water to bilged water line.

Draught.—The increase of mean draught is also arrived at in slightly different manner.

Professor Hovgaard figures first out to what extent the reduced water plane would be immersed by the water up to the original water line. To this he adds the change of trim taken at the Ψ axis. The sum is the increase in mean draught.

In our method we figure out to what extent the original water plane would be immersed by the total water inside the ship. This amount is the increase in mean draught.

Naturally both answers are the same as the change of trim at the Ψ axis is just the amount the original water plane would be sunk by the water denoted as ② and ③ as shown above.

DISCUSSION.

The President:—This paper No. 3, entitled, "Application of Buoyancy Boxes to the S. S. Lucia for the United States Shipping Board," is open for discussion.

Mr. Donnelly:—Now, it happens, you may think quite oddly or coincidentally, but still as a matter of war, that since the writing of this paper the Lucia has been torpedoed at sea, and because of that fact I desire to add in the discussion just a brief statement of these results. As is usual in human affairs, they are predicted on a theory, and therefore the results are not altogether conclusive one way or the other. They have been obtained from such sources as are available, and we will record them and leave them for the study and review of individuals, and, we hope, of modification if necessary, and the advance of our ideas.

The Lucia was torpedoed about 5 p.m. October 17th, about 1,250 miles off the Atlantic Coast on her way to the Mediterranean.

At the time of the attack the Lucia was in company with four or five other vessels, but the fleet was not convoyed.

According to the evidence of the captain and other officers, the ship was struck in the engine-room compartment just forward of the after engine-room bulkhead on the port side, so low down that the double bottom was undoubtedly destroyed, also the drainage connections for double bottom and other watertight compartments.

The explosion was so low that no damage appeared to the plating on the outside of the hull, even when the ship rolled.

At the time of the attack the Lucia was drawing 27 feet 6 inches forward and 28 feet 6 inches aft, so it will be seen that the torpedo, instead of striking as is usual not more than 10 feet below the water line, actually struck more than 20 feet. The engine-room and hold No. 5, the next compartment aft, flooded immediately, and soundings showed water entering holds Nos. 5 and 6.

The ship floated with a slight list to port during the night of the 17th, and the next day until 3.20 in the afternoon, or for something more than twenty-two hours.

The captain and gun-crew stood aboard until shortly before the sinking and stated that they were ready to fire the gun and resist submarine attack on the surface until that time. Nothing, however, was seen of the submarine before or after firing the torpedo.

About noon on the 18th the sea commenced to rise, and the wash of the sea dislodged and loosened the deck cargo of motor trucks. The drive of these trucks finally struck the hatch aft hold No. 6, which finally filled from the deck. The ship then settled aft, standing almost vertical, before she finally went down.

While the writer has received a copy of the manifest showing the loading, sufficient time has not intervened to allow a careful study of the distribution and weights of the cargo which consisted of:—Steel billets, 1,500 tons; copper, 1,060 tons; shrapnel, 1,220 tons; subsistence, 2,200 tons; hay, 1,200 tons; fresh water, 890 tons; coal, 1,088 tons; making a total of 9,158 tons.

It will be understood, as set forth in the paper, that the displacement of the double bottom had been depended upon for reserve buoyancy. This was partially eliminated by the unusual amount of fresh water carried, and the remainder by the destruction of the pump connections to the double bottom. The destruction of these connections also admitted water to all other compartments aft through the drainage connections, thus eliminating any buoyancy ordinarily maintained by watertight compartments.

Altogether it is to be noted that the torpedo in this instance made a perfect hit. It is hardly conceivable that it could be so precisely located by the hand of chance or coincidence.

At the time of the fitting out of the Lucia, ships were being torpedoed at only a moderate distance from the coast, and mainly in the English Channel and approaches thereto. Had the Lucia been torpedoed anywhere within 100 miles of the coast she would in all probability have been safe. Attention should also be called to the fact that other vessels torpedoed in the engine-room, destroying their bulkheads, have gone down in from eight to ten minutes.

It is to be regretted that four men were killed by the explosion, otherwise the crew escaped without injury.

While the result of this practical test of the Lucia is not all that was hoped for, it is,

I believe, when carefully considered in all its bearings, a very considerable contribution to the possibility of rendering ships, with the lives of their crew and their cargoes, more safe at sea.

Mr. George A. Orrok, *Member* (Communicated) :—With regard to the paper on the Lucia and the various appendices, I have been through Engstrom's mathematical review and agree with him in his conclusions, both as to the result and the time saved by the method. The metacentric height method is an heirloom of the days of ships without the regularity of form which characterizes modern freighters, but I see no reason why, with the same assumptions for a starting point, there should be any divergence in the results.

It would appear that the adoption of the non-sinkable construction for ships has at least as much to recommend it as the construction of fireproof buildings, which has become quite general in the last half century.

The President :—This paper is now before you for discussion. We will be very glad to hear from any gentleman in the room, a member or not. Is there any question you would like to ask of Mr. Donnelly?

Constructor-Commander S. V. Goodall, Royal Navy, *Member*:—I would like to say that in the early days of the war the British Admiralty, in considering the transportation of troops to France, received many proposals for making ships unsinkable, or, at any rate, difficult to sink. One of the proposals adopted was this method of filling the hold with watertight boxes.

At that time, of course, there was no experience available to indicate what success the submarine would achieve in attack upon merchant ships and transports, but it was quickly discovered that the best method of dealing with this menace was not to protect the ships in this way, but to provide efficient convoys. The lesson to be committed to memory is that the best method of dealing with the submarine menace is to concentrate attention upon the provision of the most efficient means of attack rather than to accept the enemy's attack and merely aim at making the ships unsinkable. Of course, if it were possible without grave attendant disadvantages to provide some effective means of rendering a ship more difficult to sink, it would be unwise not to do so. I use the term "difficult to sink," because the term "unsinkable" is misleading. Any ship can be sunk provided it is struck with a sufficiently large number of torpedoes.

If it be desirable to provide some means of rendering a ship difficult to sink—and that is entirely a question of policy to be decided by the naval authorities—the following are the lessons which I would draw from our experience during the war.

In the first place, we must never forget that the submarine has proved to be a very effective weapon in attacking merchant ships, and during the years of peace to which we may look forward, our efforts should be directed towards the creation and perfection of weapons that will insure that in any future war the submarine shall not be a weapon as difficult to cope with as it has been during this war.

Secondly, cargo ships should be larger, and therefore more difficult to sink by one torpedo.

Finally, and above all, stands the great lesson recorded by the committee appointed in Great Britain to consider the subject of protection against submarine attack, viz., that

all decks and bulkheads which are nominally watertight should be really and in fact watertight.

If it be desired to adopt some method such as that proposed in this paper for rendering ships more difficult to sink, I personally am of the opinion that there are far more effective methods than that advocated by Mr. Donnelly. I say this because I have seen a ship which was fitted with protection against torpedo attack safely docked after being struck by three torpedoes: and it would not be a difficult matter, in my opinion, to construct merchant ships so that on the outbreak of war they could be provided with some such system of protection which is markedly superior to that described in this paper. In conclusion, however, I desire to repeat and emphasize that it would be far better that all our ingenuity and energy should be directed towards the provision of an effective means of sinking the submarine rather than an effective means of keeping a ship afloat after it has been struck by a torpedo.

The President:—We are certainly very much obliged to Commander Goodall for the discussion of this paper. May I ask if it would be proper for him to describe the methods of protection to which he referred?

Commander S. V. Goodall:—I am afraid, sir, I could not do that.

Captain W. Hovgaard, *Member* (Communicated):—As Mr. Donnelly refers to my methods of determining the trim of a ship in the damaged condition, and as his explanation of that method on some points is not quite complete, I wish to make a few additional remarks to it.

I use the so-called "lost-buoyancy" method according to which the water that enters the ship is regarded as part of the sea, and not as a weight added to the displacement. By this method the displacement remains unaltered, and the center of gravity remains in the same position as before bilging.

The formula which I use for calculating the trim (total) when the flooded compartments are in free communication with the sea, is:—

$$t = \frac{pwrL}{W.GM'}$$

where p is the factor of permeability, and pw is the weight of water which has entered the ship up to the original water-line. This weight, of course, is a known quantity. r is the distance of the center of gravity of that water from a vertical through the center of gravity of the reduced water-line (obtained by deducting the flooded area from the original water-line area). L is the length of the ship. W is the displacement to the original water-line.

GM' is the longitudinal metacentric height found by first determining the metacentric radius BM', and subtracting from BG, the distance between the center of buoyancy and the center of gravity. The change in the vertical position of the center of buoyancy is neglected.

$$BM' = \frac{I'_2}{V}$$

where I'_2 is the longitudinal moment of inertia of the reduced water plane about a transverse axis through its center of gravity and V is volume of the original displacement.

The method employed by Mr. Donnelly is the so-called "added weight" method, where the water that enters the ship is regarded as an added weight. The displacement is augmented by that amount and the center of gravity changes its position. The two methods are equivalent and give the same result if properly applied. I prefer the lost-buoyancy method for reasons which would be too lengthy to explain in this place.

It would be of the greatest interest to the profession if the exact circumstances of bilging under which the S. S. Lucia went down were known, as it would throw considerable light on the important problem of the safety of ships at sea. Perhaps Mr. Donnelly or some other member of the Society is able to give information on that subject.

THE PRESIDENT:—Is there any other gentleman who wishes to discuss this paper? If not, a motion of thanks to the author of the paper, Mr. Donnelly, is in order.

REAR-ADMIRAL FRANCIS T. BOWLES, *Past President:*—I think the members of the Society appreciate Mr. Donnelly's courage, in the face of recent events, in coming here and so carefully explaining the methods that he has advocated. It seems to me, however, proper to say that many of us were opposed even to the conduct of this experiment, and naturally we feel that judgment was right.

THE PRESIDENT:—Is there any other expression of opinion to be given? Mr. Donnelly, do you wish to close the discussion?

MR. DONNELLY:—Just a word, Mr. President. I understood Commander Goodall to say that matters relative to the protection of the merchant ships should be left to the Navy. I should infer that he meant that the Navy Department, constituted as an arm of defense for the nation, should do this. It seems to me that the matter of the construction of the merchant ships should be left to the men primarily who ship their cargoes in the ship and place their property in the hands of the people who operate the ships. After that it should be left in the hands of the people who own the ships.

I am particularly interested, not so much in the loss of property in the time of war, great as it has been in this last war, much as it may be in wars which may come—but as an engineer I am more particularly interested in the development of the art of constructing floating craft to protect the lives and property of the people who go down to the sea in ships during times of peace.

I ask the review of this paper by my fellow-members of the Society from the point of view of its economic value, to save the destruction of life and property, the cumulative destruction of it, and on that ground I leave it before the Society for the study of those who, like myself, participate in this art, with all due confidence as to the result.

THE PRESIDENT:—I think a vote of thanks is due to Mr. Donnelly for the careful preparation of the paper. All those in favor say "Aye"; contrary-minded, "No." The motion is carried.

Mr. Donnelly will kindly accept the thanks of the Society.

We will now have the next paper, No. 4, entitled "Progress in Turbine Propulsion," which will be presented by Mr. Francis Hodgkinson, Esq., Visitor.

Mr. Hodgkinson presented the paper.

PROGRESS IN TURBINE SHIP PROPULSION.

By Francis Hodgkinson, Esq., Visitor.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

The extraordinary development of the steam turbine for land purposes, almost entirely supplanting the reciprocating engine, rendered the application of steam turbines for the propulsion of ships a natural sequence.

Sir Charles A. Parsons commenced the development of the reaction steam turbine in 1884. This was the first reduction of turbines to practice, although Dr. De Laval developed his small high-speed geared machine about the same time, and there had been some sporadic attempts at development prior to this.

Five years thereafter Sir Charles commenced their application to the small-sized central power stations then being built, he realizing the advantages of the steam turbine when built for large capacities as compared with the small lighting sets built previously.

During 1884 turbines as large as 500 kilowatts had been built for central stations in London, and at that time attention was given to the application of turbines to marine propulsion and plans were made for the building of the historic Turbinia. The progress up to that time was indeed rapid, when the limited application of high-speed machinery is considered. On the other hand, it is unfair to compare what has been accomplished in the thirty years of development of the steam turbine with the ninety years required for the reciprocating engine. In the case of the latter the mechanical arts had to be developed along with it, all of which were available for the turbine engineer.

The Turbinia was built especially to demonstrate the possibility of turbine propulsion and was of torpedo-boat type, 100 feet long, 9 feet beam, 3 feet draught, 44 tons displacement, and was completed in 1895.

The first machinery comprised a single complete expansion turbine of radial flow type direct connected to the propeller. The turbine was intended to develop 2,000 horse-power at 2,000 to 3,000 revolutions per minute. There were but little data available at that time concerning propellers to operate at such speeds, and several propellers were tried with no particular success. The trials of these several propellers would be of much interest if their records were available. They led to extensive experiments on the part of Sir Charles regarding cavitation.

It was not until in 1896 that anything like success was attained when the Turbinia's machinery was changed over to three compounded turbines, the steam passing them in series, each driving one of the three propeller shafts, and each shaft

carrying three propellers. Tests were carried out in 1897 and 32.76 knots mean speed per hour was attained.

The application of turbines to marine propulsion became very rapid, and the construction of the turbine as applied to the larger ships called for the greatest skill of the designer, in regard to which no words of the author could pay adequate tribute.

The engineering skill required in the design of the modern high-speed geared turbine bears no comparison to that required for such gigantic engineering undertakings as the direct-connected turbines of the Mauretania, the Lusitania, or the Carmania, for example.

It became early apparent that, because of the disparity between the best speed of the turbine and the propeller, there was a distinct line of demarcation, about 17 knots, below which the application of turbines was not economical, which naturally debarred not less than some 90 per cent of the vessels afloat.

In 1904 turbine marine propulsion had reached such stages that by the end of that year some twenty-six vessels, aggregating 147,000 horse-power, were in service, which created enough interest to lead George Westinghouse to consider entering the marine field.

At his instigation the late Admiral G. W. Melville, U. S. N., and Mr. John H. Macalpine visited Europe in 1904 to report on the marine situation as it then existed, and it is interesting to note that, in spite of the large number of vessels equipped in Europe, the report was anything but encouraging. They did not see any opportunity for the steam turbine for driving ships as compared with the existing reciprocating engines, particularly in the case of ships which are required to operate at cruising speeds, and they showed how inferior were the turbine installations as compared with the reciprocating engine installations when so operated. They recognized the applicability of the turbine to express steamers which always operated at their full speed, and pointed out their lack of economy when applied to lower speed ships which comprise the greater part of the merchant marine. They said, "If one could devise a means of reconciling in a practical manner the necessary high speed of revolution of the turbine with the comparatively low speed of revolution required by an efficient propeller, the problem would be solved and the turbine would practically wipe out the reciprocating engine for the propulsion of ships. The solution of this problem would be a stroke of great genius," and proceeded some time thereafter themselves to become the genii by designing a tooth reduction gear adaptable to such service, embodying the now well-known floating frame.

Mr. Westinghouse at once recognized the great possibility of its construction, and though considerably delayed on account of the financial depression at that time, a reduction gear expected to develop 6,000 horse-power, reducing from 1,500 to 300 revolutions per minute, was tested in 1909.

The inventors recognizing that no gear was suitable for shipboard use that was not capable of successfully operating with considerable misalignment. the gear was operated with the pinion deliberately set out of alignment 0.020 inch in the length

of the pinion, thus demonstrating the adaptability of the floating frame to its intended function.

While this demonstration plainly opened the way for the application of the steam turbine to the driving of all manner of ships without reference to speed, obviously permitting fuel costs to be reduced in amounts of 15 per cent to 20 per cent, the application to ships was slow, possibly because of the small number of ships being built in this country and undue conservatism on the part of shipowners. The reduction gear was, however, applied to a large number of land installations with uniform success. It is argued by many that the performance of land machinery can be no criterion of its suitability for marine work. This is particularly true in the respect that alignment once secured on land will generally remain unimpaired for an indefinite period, while, on the other hand, continual disturbances of alignment of necessity will obtain on ships. There is one respect, however, in connection with these gears in which their application to land work is more exacting than in marine work, owing to the much greater inertia of the slow-speed generator as compared with the ship propeller. The gear operates between much more massive fly wheels than in the case of the marine installation, demanding extreme accuracy of gear cutting, so far as any errors of pitch which might result in any unequal angular velocity are concerned. Any errors of this character, quite unobservable when the gear is driving the relatively low inertia ship's propeller, will rack and pound badly when driving heavy generators.

In spite of the advantages offered by the geared turbine there were but few installations contemplated in this country until the complexion of the shipbuilding industry was completely changed by the war, although the collier Neptune was equipped and contracts were placed for the destroyer tender Melville, as well as the cruising gears for some battleships. Parsons had, in 1910, done some exploiting with the fixed bearing gear in the S. S. Vespasian, transmitting 500 horse-power per pinion.

So far as land gears are concerned, Table I shows those constructed by the Westinghouse Company up to 1915 and since:—

TABLE I.

Size, horse-power	Built before 1915	Built after 1915	Total	Aggregate total horse-power
1 to 300	27	400	427	42,951
300 to 500	17	24	41	48,582
500 to 800	10	30	40	25,312
800 to 2,000	14	26	40	50,314
2,000 to 6,000	5	5	10	30,675
Totals.....	73	485	558	197,834

In addition to this a large number of fixed bearing gears were built, and at one time during this period, with the view of reducing costs, fixed bearing gears were built in sizes as large as 500 kilowatts, the results of which were not encouraging, so that at the present time these are not built in sizes larger than 300 kilowatts, which is regarded by the Westinghouse Company as the extreme limit for fixed bearing construction. The flexibility of the floating frame, as the design was originally developed by Melville and Macalpine, was obtained by the pinion frame being supported on a flexible steel member as indicated in Fig. 1, Plate 28. This was later modified by the construction shown in Fig. 2, Plate 29, by Mr. Westinghouse, for the purpose of incorporating therewith a dynamometer which would measure directly the reaction on the pinion bearings. Oil was taken from the film, which is at high pressure within the bearings, and led to within the cylinders "B," one located beneath each of the three bearings where the pressure was regulated by letting a portion of the oil escape by the automatic valve "C," thus balancing the pinion frame upon the pistons at a fixed distance above the bed. By reading the pressure within the cylinders and determining the revolutions, the horse-power being developed may be at once determined. The construction, however, lacks the extreme simplicity of the original design and for that reason is not employed except in cases where a dynamometer feature is demanded, in which case the combination of the two is employed as is shown in Fig. 3, Plate 30. When normally operating, the floating frame is bolted to the base of the gear case and the flexibility is obtained by the flexible steel member as in the inventor's original design. The bolts that secure the frame to the bed may be loosened and, by means of an auxiliary oil pump, oil is admitted to a single cylinder in sufficient quantities to raise the frame a slight distance and the pressure observed. The power developed is calculated therefrom as in the other case. Whenever desired, the horse-power may be determined in a manner not unlike that of taking indicator cards of reciprocating engines.

The essential features of the floating frame gear will be but little referred to here in view of the many articles that have been written on this subject by Mr. Macalpine.*

The point most freely discussed in connection with reduction gears is the permissible tooth pressure per lineal inch of tooth face. Unquestionably the safe load which can be transmitted by the gear teeth is all-important, but unfortunately the subject has been frequently regarded as entirely independent of any other feature of the reduction gear design. This is a mistaken view. The ultimate limit of pressure which the teeth can safely carry has not been determined, but the pressures at present in use among designers are only possible with the most accurate alignment. No comparison of tooth pressure is therefore reliable without careful consideration of the methods used to maintain the unit pressure within the limits for which the design was made. Faulty bearing design, inadequate support or improper couplings may be individually or collectively responsible for deranging the align-

**Vide, London Engineering,* dated September 17, 1909, May 5, 12, 19, 26, and June 2, 9 and 16, 1916; Proceedings of Engineers' Society of Western Pennsylvania dated December 18, 1917; Institution of Naval Architects, London, March 29, 1917.

ment, resulting in a concentration of the tooth load and often failure of the teeth. It is obvious, then, that merely to limit the unit tooth pressure to some fixed empirical figure for all gears in no way insures the safety of the teeth. On the other hand, anything which tends to maintain the alignment of the teeth and to prevent concentration of pressure is to be welcomed as a source of safety in the operation of the gearing. It is for this reason that the Melville-Macalpine invention of the I-beam support for the pinion bearings is so thoroughly justifying the claims made for it. The closer this mechanically correct device is investigated, the more apparent becomes its most important function, namely, to maintain automatically a very uniform distribution of tooth pressure under the most severe distortions of the gear case that can occur in the frailest hull. Its value in permitting higher unit loads than are customary on what have been termed "rigid bearing" gears is graphically illustrated in Fig. 4, Plate 31.

The curves of the rigid bearing dimensions have been compiled from recent marine practice in Great Britain. The floating frame figures are those used by the Westinghouse Electric and Manufacturing Company for marine work, and there are points indicated on this curve showing gears actually in service.

As previously referred to, the gear, by permitting high turbine speeds, much simplifies the turbine design. It enables a speed to be selected for the turbine appropriate for best economy. Furthermore, it inherently permits a design of increased reliability by virtue of sensibly reduced dimensions.

The small high-speed geared turbines require few of the elaborate precautions in warming up and getting in service that must be practiced with the large direct-connected turbines.

Gears may readily be arranged with two pinions for even the smallest single screw steamer, permitting the employment of what are known as cross compound turbines; that is, a high-pressure and a low-pressure turbine, the steam passing them in series. Piping is arranged that by the manipulation of valves the high-pressure turbine may exhaust direct to the condenser, or the high-pressure turbine be isolated and the low-pressure turbine receive high-pressure steam direct. Thus, generally speaking, no turbine or gear accident is likely to so incapacitate the machinery that the vessel cannot reach port at reduced speeds. There is one record of a 10½ knot steamer, which, on account of breakage of one pinion, crossed the Atlantic with the low-pressure turbine alone, obtaining speeds as high as 9 knots.

The general arrangement of such an installation is shown in Fig. 5, Plate 32. Its reliability has much to commend it. This is not only due to the flexibility above referred to, but further due to the simplification of the turbines themselves. Each turbine only expands the steam corresponding to half the heat drop, and so has a much reduced number of turbine elements, smaller temperature range, and reduced length between bearings as compared with a complete expansion turbine, having similar economy. Both high and low-pressure turbines are provided with reversing elements arranged in a similarly compounded manner to the ahead elements, thus rendering maneuvering possibilities as complete with one turbine element operating

as with both. A compact arrangement of the double pinion double reduction gear representing latest practice is shown in Fig. 6, Plate 33.

Of necessity the cross compound turbine installation with its double pinion gear is more costly than the single complete expansion turbine, and with keen competition will not be installed unless shipowners recognize its manifest advantages. So far as the writer has observed, owners seem quite indifferent to the probable reliability of machinery so long as they secure insurance and the protection of the classification societies. The plea is therefore made by the author that underwriters, in collaboration with the classification societies, should discriminate in insurance rates between types of installations having manifestly differing degrees of reliability.

No doubt single-screw steamers will frequently be driven by single complete expansion turbines, at least for low powers. An example of a small sized installation 1,500 horse-power is shown in Fig. 7, Plate 34, and attention is called to some of its features. The double reduction gear elements are arranged one above the other with the high-speed pinion uppermost. This elevates the turbine axis and permits the condenser to be located immediately below the turbine, permitting the exhaust to issue from the under side of the turbine and pass vertically downwards to the condenser, much simplifying the removal of water. One end of the turbine is carried directly upon a bracket integral with the gear case, the other by the exhaust outlet being set directly upon the condenser. The condenser is secured by its upper surface to seatings, eliminating disturbances to alignment on account of expansion of the condenser.

There appears to be much apprehension in the matter of the reliability of turbine-geared steamers, and if current rumor may be relied upon there have been many failures, which, with more careful design or by employing the best in the art, would seem to have been wholly unnecessary. To correct such an impression, Table II gives a list of all vessels equipped with the floating frame gear and Westinghouse turbines. The table states the date on which the vessel entered service, the power of the installation, and approximately the miles traveled up to the present time (September 1, 1918).

Some troubles have been experienced as are certain to occur with all kinds of machinery. Since there must be a large human element, footnotes are appended, plainly stating the character of the troubles.

TABLE II.

Name of ship	Where built	S. H. P. per ship	Date in service	Miles traveled (approx.)	Troubles in service	Remarks
Melville	New York S. B. Co.	4,000	11- 1-15	7,000	None	U. S. T. B. D. tender main gear only
Neptune	Maryland Steel Co.	6,500	12- 1-15	128,000	See note A	U. S. collier
Malmanger	Chester S. B. Co.	2,900	3- 8-17	2,500	None	Sunk 3-23-17
Westwood	Ames S. B. Co.	2,500	3-24-18	16,000	None	
Maui	Union Iron Works	10,000	4-17-17	60,000	See note B	
Golaa	Chester S. B. Co.	2,900	7- 6-17	36,000	See note C	
Hisko	Chester S. B. Co.	2,900	12- 4-17	25,000	None	
Coronado	Moore S. B. Co.	2,400	1-29-18	27,000	None	
Yosemite	Moore S. B. Co.	2,400	2- 2-18	27,000	None	
Westerley	Ames S. B. & D. D. Co.	2,500	2-27-18	7,600	None	Sunk 4-29-18
Sudbury	Chester S. B. Co.	2,900	3- 5-18	15,000	See note D	
West Eagle	Ames S. B. & D. D. Co.	2,500	4-12-18	11,000	None	
Yellowstone	Moore S. B. Co.	2,400	4-25-18	22,000	None	
Overbrook	Chester S. B. Co.	2,900	4-30-18	16,000	None	
Oakland	Moore S. B. Co.	2,750	5-30-18	12,000	None	
Accomac	Los Angeles S. B. Co.	3,000	6- 6-18	12,000	None	
Avondale	Chester S. B. Co.	2,900	6-23-18	6,000	See note E	
Wakulla	Los Angeles S. B. Co.	3,000	6-26-18	.....	None	
West Ford	Ames S. B. & D. D. Co.	2,750	6-30-18	8,000	See note F	
Wampum	Los Angeles S. B. Co.	3,000	7- 9-18	.....	None	
Wassiac	Los Angeles S. B. Co.	3,000	7-25-18	.....	None	
Montrolite	Ames S. B. & D. D. Co.	2,500	8-12-18	5,000	None	
West Galoc	Los Angeles S. B. Co.	3,000	8-13-18	.....	None	
West Gleata	Los Angeles S. B. Co.	3,000	9- 5-18	.....	None	
Polar Sea	Baltimore D. D. & S. B. Co.	1,800	9- 6-18	.....	None	
Phoenix	Chester S. B. Co.	2,900	9- 7-18	.....	None	
Pennsylvania	Newport News S. B. Co.	3,200	Not known	Not known	None	U. S. battleship cruising gears only
Arizona	New York Navy Yard	4,000	Not known	Not known	See note G	Do.
Mississippi	Newport News S. B. Co.	3,000	Not known	Not known	None	Do.
Henley	Re-engined at Philadelphia Navy Yard	14,000	Not known	Not known	None	U. S. T. B. D.
Mayrant	Do.	13,500	Not known	Not known	None	U. S. T. B. D.

NOTE A.

U. S. S. Neptune.—This ship was equipped with two sets (twin screws) single reduction gears and turbines, the turbines having been largely experimental and were not successful. The gears, however, operated splendidly. The turbine machinery was then replaced, and inasmuch as a higher turbine speed was considered desirable, new gears involving a greater speed reduction were also installed at this time. The designed constants of the new gears were very high and are still much in advance of our present practice.

Considerable trouble was experienced due to the teeth abrading, which was only overcome by the use of lard oil. Since that time, however, in November, 1915, no further trouble has been recorded, and the teeth at the last inspection were in good condition without any indication of wear.

NOTE B.

S. S. Maul.—This vessel was built by the Union Iron Works. Inasmuch as we were late in delivering the machinery, we were unable to carry out any tests on the gears in the works, and inasmuch as great store was set by the owners that nothing should go wrong on the maiden voyage, and as there was some uncertainty as to the excellence of the tooth surfaces, lard oil was employed as a lubricant for the first two voyages, after which mineral oil was substituted for the lard oil.

The operation of the machinery was all that could be desired for eight voyages, at which time there was abrasion of the gears due to failure of the lubrication. This was discovered in Honolulu and the ship returned to San Francisco with nothing being done to the machinery except an attempt to clean the oiling system. The tooth surfaces smoothed up considerably during the voyage.

The gears were then transposed from one side to the other so as to make what had been the astern surfaces the ahead surfaces, so as to use uninjured tooth surfaces for ahead operation.

Again because of some uncertainty of the tooth surfaces lard oil was employed as a lubricant and the vessel entered in government service, going to Chile for cargo and proceeding to Baltimore. During the voyage there was an accident to an oil cooler, admitting salt water to the system. The shipbuilder having provided no means of removing any water, the effect of the salt water on the lard oil was to turn it violently acid which necessitated a complete overhauling of the machinery on its arrival in Baltimore.

On this being completed and on the trip from Baltimore to New York trouble was experienced with abrasion of the tooth surfaces due, it was believed, to an inferior quality of oil, together with further failure of the oil cooler, admitting enough water to the system to make an emulsion of approximately 30 per cent. A better oil was substituted and nothing was done to the tooth surfaces, the vessel having made one voyage to Europe and back with no trouble so far as the gears are concerned.

During this voyage trouble was experienced with one of the turbines, causing quite an extensive repair because of an obstruction in one of the oil passages to the thrust bearing of the turbine, causing the thrust bearing to fail; the turbine rotor, moving endwise, completely wrecking the labyrinth packing between the ahead and astern elements and buckling the rotor.

NOTE C.

S. S. Golaa.—Norwegian oil tanker built by Chester Shipbuilding Company and chartered by British Admiralty. Put in service July 6, 1917. Made three round trips to English ports. At present in coastwise trade between Port Arthur, Texas, and Philadelphia or Bayonne. Towards end of last trip from Europe (February, 1918) some teeth on starboard high-speed pinion broke out. This gear was disconnected and ship made port, using low-pressure turbine only. Inspection showed break occurred on one helix, 3 inches from end of tooth face. There was no evidence of wear on any of the tooth faces, the undamaged portion of broken tooth face indicating uniform distribution of load. This fact and the position of fracture make certain accident was due to defective material.

In August of this year the high-pressure turbine suffered injury as a result of improper setting of the turbine thrust bearing. Shortly thereafter an accident occurred to the pinion which replaced the one originally defective. The character of the broken tooth was similar to the previous one. The broken parts have not yet been received to enable a careful examination of the material to be made.

NOTE D.

S. S. Sudbury.—An American freighter built by the Chester Shipbuilding Company for the Shawmut Steamship Company. It is at present being operated by the U. S. Naval Overseas Transportation Service. A few days after leaving France on return half of maiden voyage, some teeth broke out of starboard high-speed pinion. This gear was disconnected and ship returned to New York, using low-pressure turbine only, with which 9 knots was attained, the designed full speed being 10½ knots.

On arrival at port, inspection showed no wear, the tooth load having been well distributed on all tooth

faces. Several teeth were cracked. Subsequent examination of steel indicates defective material, most probably due to faulty heat treatment, the fracture indicating the steel had been burned. This was confirmed by discovery that some teeth in port high-speed pinion were also cracked, although no failure occurred in service. Both pinions were forged from the same billet and treated at the same time. These pinions are similar as to material and design with twenty-five other pinions now in successful operation.

NOTE E.

S. S. Avondale.—An American oil tanker, built by the Chester Shipbuilding Company and being operated by the Pan-American Oil Company for the United States Shipping Board. Just as ship was leaving Philadelphia for trial trip a heavy blade rub was heard in high-pressure turbine. Inspection indicated defective workmanship. Some of the rotating blades were loose as a result of having been improperly put in. The spindle was rebladed and ship proceeded satisfactorily from Philadelphia to New York. This turbine is a counterpart of twelve others now in successful operation on various ships.

NOTE F.

S. S. West Ford.—This vessel left Seattle at 5 p. m. on July 14, 1918, on her maiden voyage to an Atlantic port. Seven hours out from Seattle, oil commenced foaming out from the turbine, running over the engine-room gratings. The chief engineer was called and, instead of investigating the reason for augmentation of the oil, he was content to pump 200 gallons to a reserve tank. Later the same thing occurred, oil again running out on the gratings, and later still at 2.14 a. m., the high-pressure turbine commenced vibrating so badly that it interfered with their lighting system. They shut down to remedy the matter of the lighting system, and on trying to start the turbine it required 125 pounds initial pressure to revolve it. Serious vibration was again in evidence so the Chief decided to do what he termed "crank up on the thrust." It was impracticable to anchor so they returned to Port Townsend at 40 revolutions per minute. They then made an observation of the oil in the drain tank, and on removing the cap the oil squirted to the roof of the shaft alley. It was later discovered an oil cooler tube had split, admitting large quantities of salt water to the oil system.

Instructions had been given that the level of the oil in the drain tank should be regularly observed, and it is incomprehensible that it was not at once obvious that something was getting in the oil system from some exterior source. Merely looking at the oil would have determined this was salt water. Then all that would have been necessary was to shut off the water service to the cooler and separate the relatively small quantity of salt water from the gravity tank, and there need have been no interruption whatsoever. The result of such neglect was for the bearings, for want of lubrication, to let the rotor down, causing considerable injury to the turbine.

NOTE G.

U. S. S. Arizona.—On a voyage from Cuba to the United States the teeth of one of the crusing gears scored. Subsequent investigation showed that the oil pumps had stopped and the supply to the gears had failed. The teeth were dressed up and no further trouble has been experienced.

As in land installations, the overall economic performance is not dependent on the prime mover alone. High performance is not to be secured without care being bestowed on all the ancillary apparatus, attention to matters of heat balance with the feed water heater, condensing apparatus capable of performing with a close approach to the ideal, etc.

Large size land turbines have been built which deliver to the shaft not less than about 80 per cent of the theoretical energy available from the steam expanding between the limits specified, so that further improvements in the turbine itself will not materially raise this efficiency. Further improvement in economy must be looked for from causes other than the prime mover itself. This is a subject of the greatest importance in view of the rapidly increasing cost of fuel, and it justifies considerably more capital expenditure for economizers and other such apparatus which will reduce fuel cost.

The engineer of our large central stations is subject to keen competition and is confronted almost solely with the problem of producing reliable energy for the least cost, including fixed charges. He has before him daily statements showing his overall power costs with a high degree of accuracy, resulting in considerable success on his part in the production of low power costs.

It is therefore not unreasonable that the marine engineer might look to the central station engineer for advancement from some of the latter's best practice. It is of course understood that complete standby machinery is not available for the marine engineer, neither can the superintending engineer direct those in immediate charge of the machinery by frequent visits. Hence there is the more urgent call for the greatest reliability and simplicity of the marine installation; though, after all, perhaps not more than that which the central stations have in our big cities. An interruption to service, however brief, is regarded most seriously.

FEED WATER HEATING SYSTEMS.

It is common practice on shipboard to provide a closed or tubular heater to which is led the exhaust steam from the auxiliary machinery, which latter exhausts at a pressure between 5 and 10 pounds gauge. The exhaust system is provided with a connection to let any proportion of this steam to the condenser. Sometimes again there is a hand valve, permitting any surplus of this steam to be taken to a low pressure stage of the turbine, all of which calls for hand manipulation where the conditions are sometimes quite variable, owing to more or less intermittent operation of the feed pump. Sometimes the connection to the condenser is provided with a spring loaded valve so that when the exhaust pressure reaches a predetermined pressure, higher than that within the condenser, steam may pass to the condenser. The construction of the valves usually employed is such that the higher the pressure in the condenser, the higher is the pressure at which the steam will pass to the condenser, which is of course undesirable. A system which will automatically maintain a predetermined temperature in the feed heater at all times, bleeding the main turbine for this purpose, at high powers if necessary, and at the same time automatically permit any surplus steam not condensed in the feed water heater to do useful work in the turbine, is much to be desired.

Heat balance systems have for some time been available for land purposes, there being provided automatic valves so that whenever there is a surplus of auxiliary exhaust steam this surplus may pass through a low pressure stage of the turbine, doing work therein at the rate of 20 to 22 pounds per horse-power. Other types of valves are available for land installations which will not only take surplus steam into the turbine at times of light loads on the main unit at which time the auxiliaries will obviously furnish too much exhaust steam; but, on the other hand, they are arranged to deliver steam from the turbine to the feed water heater at times of heavy loads when the stage pressures in the turbine are relatively high and there is a deficiency of steam for feed water heating. The latter should particu-

larly find a place on war vessels which are required to operate for long periods at different speeds, where there is a widely varying ratio of steam used by the auxiliary machinery to that used by the main turbines. In merchant vessels this ratio is more nearly constant, but nevertheless careful study to the end of obtaining a complete heat balance will be advantageous. Details of the two forms of valves above described are shown in Fig. 8, Plate 35, and Fig. 9, Plate 36.

The valve shown in Fig. 8 is intended for cases where there is never a deficiency of auxiliary exhaust steam for feed heating. It comprises a piston having atmospheric pressure above it, and the auxiliary exhaust steam below. When the auxiliary exhaust steam pressure rises a sufficient amount above the pressure of the atmosphere to raise the piston, steam may pass to the turbine. Air leakage into the turbine is entirely precluded by ample steam seal around the piston furnished by the auxiliary exhaust steam. The piston may be loaded to any feed heater pressure desired. The upper cylinder is to forcibly close the valve in the event of the turbine over-speeding.

The modification of this valve shown in Fig. 9 is adaptable where there is at times a deficiency of auxiliary exhaust steam. Any time the stage pressure in the turbine is greater than that in the heater, the lower piston will rise, permitting passage of steam from the turbine to the heater, at the same time, when required, permitting flow to the turbine as in the case of the valve shown in Fig. 9.

It sometimes occurs that the turbine is subjected to such overloads that a stage of the turbine selected to give the desired heater pressure at moderate loads would be far too high for the heater at overloads. In this instance the modification shown in Fig. 10, Plate 37, may be employed which limits the pressure in the heating system in accordance with the spring adjustment regardless of how high the pressure may be in the turbine.

It is the universal practice to employ closed tubular heaters in marine work, while in land work what is known as the open heater is the rule. With the advent of turbine-driven auxiliaries and electrically operated winches, etc., the auxiliary exhaust may be uncontaminated with oil, permitting the employment of an open heater for shipboard use, and a more complete separation of air from the feed water. As this type of heater contains no tubes, the heating steam mixes with the feed water, as in a jet condenser, so its cost is materially less. Frequently these heaters are open to the atmosphere, and hence their name, but when working in connection with the heat balance system they must obviously have no open outlet, merely a provision for the separation of air, and a relief valve for safety. Such a type of feed heater eliminates need of a separate feed tank and must be located some feet above the feed pumps to preclude the latter being vapor bound because of pumping water near the temperature of evaporation.

STEAM PRESSURES.

The attention of central station engineers at the present time is being directed to employing higher boiler pressures, viz., pressures as high as 600 pounds. To-day

200 pounds pressure and 200° F. superheat are regarded as a more or less everyday operating condition for large plants. Steam generated at 600 pounds pressure, having exactly the same heat content as that contained in 200 pounds pressure and 200° F. superheat, will have a superheat of approximately 128° F. This, expanded to 29 inches of vacuum, is theoretically capable of giving 13 per cent more energy than when generated at 200 pounds and expanded to the same vacuum. Doubtless, when operating under the high-pressure conditions, the turbine will be of lower efficiency. The high-pressure element will be less efficient on account of the great density and the small volume of the steam, and on the other hand the low-pressure elements will be less efficient because of the great amount of water precipitated by the steam expansion from the high pressure, introducing a brake in the turbine. However, it is reasonable to suppose that the turbine will avail itself of at least 50 per cent of this 13 per cent possibility, producing a net saving of 6 or 7 per cent. What may be expected to be derived from higher pressures is exhibited in Fig. 11, Plate 36, and Fig. 12, Plate 37, plotted for various pressures.

ECONOMIZERS.

So far as the author is aware, economizers have not been employed in marine installations. It would seem that their capital cost would be well warranted for the case of express steamers operating always at their maximum speed. In the case of 250 pounds gauge steam pressure there is a 16 per cent saving in the work of the boiler by a feed temperature of 375° F. as compared with 212° F. To this gain there must be made a deduction of the energy expanded by the induced draft fans and the scrapers for the economizer surfaces. A net gain of 10 per cent should be readily realized. Their installation would seem to present no particular difficulty as is shown in Fig. 13, Plate 40.

SUPERHEAT.

With the old direct-connected turbines, superheat has never been recommended, and wisely so considering their immense structure. Even with the much smaller high-speed geared turbines as high superheat as is desirable in land installations may not be practicable at sea on account of the rapid stopping, starting, etc., necessary for quick maneuvering, which may cause uneven heating and cooling. In the author's opinion superheats as high as 100° F. should present no operating difficulty whatsoever with well-designed high-speed turbines. 100° F. superheat will affect the steam consumption not less than 8 per cent as compared with dry saturated steam, probably saving some 4 or 5 per cent in fuel.

CONDENSERS.

Inasmuch as turbines may be designed to expand the steam to vacuum of 29 inches, and as the steam consumption with such a turbine will be 7 per cent bet-

ter with 29 inches vacuum than with 28 inches, providing it be designed to expand to such low pressures, the necessity of providing sufficient well-disposed surface to produce such a vacuum is not only obvious, but it is furthermore necessary to have a complete understanding of what constitutes good condenser performance with the apparatus available.

An important detail is the drop in steam pressure through the condenser. For good practice this should not exceed 1/10 inch mercury. The air pump should be of a type capable of completely evacuating the non-condensible vapor from the condenser so that the condenser shell shall contain nothing but steam, and therefore be of the same temperature throughout except for the small pressure drop within the shell itself. To produce this condition requires not only excellent air removing apparatus, but constant vigilance in the elimination of air leaks. It is the practice of certain large central stations to provide an air bell, which may on occasion be connected to the discharge of air pumps, by means of which the air leakage may be measured. With 40,000 horse-power units, 3½ cubic feet per minute of free air is considered good practice, and should this reach to seven it is the signal for a search to discover the source of the leak. Such a practice would be impracticable on shipboard and only serves to point out how central station engineers regard the ill effects of air leaks.

With such a condenser having practically uniform steam temperature throughout the shell, there is the greatest temperature difference between circulating water and steam in the bottom pass (assuming steam enters at the top and water at the bottom); while, on the other hand, in the top pass there is but a small temperature difference. Hence much more steam is condensed at the bottom than at the top, contrary to what is usually experienced with condensers that do not have the non-condensible vapors completely evacuated. This calls for especial care in having paths for the passage of steam through the upper zones of the condenser to insure the minimum pressure drop.

With the complete evacuation of the non-condensible vapors, the vacuum should correspond to a temperature not to exceed one or two degrees higher than the temperature of the condensed steam leaving the condenser, which is a point that should be kept constantly under observation.

OILING SYSTEMS.

While the oiling system can bear no relation to the economics of turbine propelled ships, it is of vital concern to the reliability of operation, and too much care cannot be given to the layout of the system to the end of obtaining the extreme degree of simplicity and reliability.

It has been generally the custom in Westinghouse installations to provide oil pumps directly driven by gearing connected to the main gears. The double-pinion double-reduction gears, of which a large number have been built, have two oil pumps, one driven from each intermediate gear shaft. The design contemplated for the

sake of reliability that each oil pump alone be large enough for the system. These pumps are relayed by an auxiliary steam-driven pump for use when maneuvering. The direct-driven pumps have been objected to in some quarters and duplicate steam-driven pumps substituted therefor. The advantage of the latter, while no doubt lacking the extreme reliability of the direct driven pumps, is that, when properly controlled, it need only pump the oil needed by the system instead of say three times as much, which no doubt will have much to do with increasing the life of the oil as well as simplifying the filtering or straining systems. What is regarded as an ideal system is shown in Fig. 14, Plate 41. It has the following features:—

1. The pumps are located at as low a level as possible to reduce the suction head to the extreme limit.

2. The drain tank is of as large a dimension as practicable, and is located sufficiently low to insure the oil draining freely to it from the machinery with ample sized pipes, and assurance that with the extreme rolling and pitching there will be no leakage from the bearings.

3. The pump suction should be several inches above the bottom of the tank to avoid drawing dirt and emulsion from the bottom.

4. It is regarded as desirable to employ an additional suction from the bottom of the tank by means of which dirty oil may be pumped through a filter and to permit complete emptying of the tank for cleaning purposes.

5. The pump is arranged to discharge its oil through coolers to an overhead gravity tank located some twenty feet above the machinery.

6. Duplicate coolers are employed so that while one set is in use the other may be cut out of service. They should be by-passed with a spring loaded check valve, loaded to some amount greater than the resistance of the cooler so that under no conditions can mishandling of the valves cause interruption to service.

7. An overhead gravity tank is provided with three strainers having successively finer mesh. The photograph of one of these strainers is shown in Fig. 15, Plate 42. The screens are successively of finer mesh, the first being sheet metal with 1/16 inch perforations, the second thirty-mesh wire gauze, the last seventy-mesh wire gauze. In the event of these becoming choked there can be no interruption to service, for the oil merely flows over the top, when they may be readily removed for cleaning. The screens are secured to quite large cast frames arranged as shown in Fig. 15, so that any dirt falling from the screen on their being removed will be caught in the frames and thus removed.

From these the oil passes through a fractional filter, that is, some of the oil runs through filter bags and is thoroughly filtered, the rest overflowing.

The gravity tank should be provided with a very rugged float of large power for controlling the speed of the oil pumps.

The outlet from the tank to the machinery should be well above the bottom and there should be other means of drawing oil from the bottom of this tank to a filter or settling tank. The character of the oil in the bottom of this gravity tank

should be regularly observed to be sure that the water is not entering the system from any source.

8. The system which provides a settling tank, capable of taking a complete charge of oil for the system, is to be recommended.

9. It is considered desirable that the oil coolers should be arranged, if possible, to have the oil pressure superior to the water pressure, so that a loss of oil will occur rather than the admixture of salt water. The former would be shown by the oil level indicator in the lower tank.

There are installations, such as destroyers, where there is but little head room and where a gravity oiling system is impracticable, and a pressure oiling system must be employed. In this case twin strainers or their equivalent must be resorted to. These are of course dangerous because of them becoming choked and interrupting the service, or bursting and letting dirt through if the pumps are sufficiently powerful. If they must be employed they should invariably be by-passed through a spring-loaded check valve, loaded to say one-half pound, so that with a slight increase of resistance of the strainers the oil will by-pass them and the service never be interrupted.

Concerning arrangements of the turbines themselves, a design of a single complete expansion unit has already been referred to. The general design of the cross compound units is shown in Fig. 16, Plate 43, and Fig. 17, Plate 44. The receiver pressure between the high and low-pressure elements approximates 5 pounds gauge at full power, rendering it adaptable for connection to the auxiliary exhaust steam and the feed heater as has previously been discussed. The detail construction of these turbines, method of inserting blades, etc., etc., will not be dealt with in detail here as already much has been written concerning them,* except those details which apply particularly to marine work.

The turbines illustrated in Figs. 16 and 17 are essentially for vessels always operating at their maximum speed and are subject to modifications on ships where cruising speeds are involved. One of these, known as the "divided flow" type, is shown in Figs. 18 and 19, Plates 45 and 46, and are the turbines applied to a Swedish cruiser. The combination comprises an impulse element in the high-pressure turbine through which passes all the steam to the system. The nozzles are arranged in groups, each under valve control so that the turbine may realize substantially full pressure at the nozzles with widely differing volumes of steam flow. The general arrangement of this combination is shown in Fig. 20, Plate 47. After passing the impulse element the steam divides, one portion continuing through the same turbine to condenser pressure; and a slightly greater portion passing over to the low-pressure element through which it expands to the condenser. For cruising the one low-pressure element may be cut out of service, the steam closed to certain nozzles, and the turbine operated with fair economy at the reduced power. The reason for a greater proportion of steam passing to the low pressure is in order that the work may be equal on the two pinions at full power.

*See *Electric Journal* for January, February, March, April, 1918.

This divided flow combination is adaptable to constant speed steamers and will generally give nearly as good performance in steam consumption as the cross compound unit previously referred to; and it has one advantage, that reversing elements may be placed in both turbines as in the cross compound unit without the need of the labyrinth packing between the ahead and astern exhaust chambers in the high-pressure elements. Although not being compounded one with the other, the reversing elements are not as economical as the cross compound unit first described. At full power the steam passes in parallel through three sets of low-pressure blades (if the low-pressure turbine be double flow), thus permitting smaller turbine diameters or higher rotative speeds, or both if desired, without reducing the adaptability of the turbine to expand to low pressures. This type of installation has the advantage of smaller cross connecting pipes than the straight cross compound.

There is a further modification of these arrangements known as the "series divided flow" as illustrated in Fig. 21, Plate 48, which provides for certain of the turbine elements being operated in parallel for maximum powers and in series for reduced powers. It will be observed from the figure that the blade proportions work out with approximate corrections for either the series or the parallel condition of operation. This combination renders unnecessary the installation of a separate turbine for use when cruising. The relative performances of these respective types of turbines are exhibited in curves, Fig. 22, Plate 49.

Some installations have been made where cruising turbines have been employed and attention is called to the arrangement for coupling the cruising turbine, shown in Fig. 23, Plate 50. It has been regarded in the past as desirable that the cruising turbines be arranged so that they may be operated when connected to the main turbines at the maximum speed of the main units, the idea having been that should the engineer go up to full power of the vessel and forget to disconnect this cruising turbine, no injury would result therefrom. This meant that when the cruising turbine was in service it had to operate at very low blade speeds and be therefore quite heavy or the cruising turbine cannot be arranged to be very economical. It is the practice of the Westinghouse Company to design the cruising turbine geared to the main turbine and designed for the speeds at which it is required in service, which would be dangerously high should it not be disconnected at full power.

The design shown in Fig. 23 provides that should the cruising turbine operate above a predetermined speed, steam will automatically be shut off from it and the clutch automatically opened. The arrangement of this installation provides that the steam maneuvering valve is employed whether the cruising turbine is in operation or not. Means are provided for readily synchronizing the cruising turbine to the speed of the main turbine and throwing the clutch without affecting the speed of the vessel, provided it is running at speeds corresponding to that at which the cruising turbine should be operated.

An interesting equipment suitable for patrol boats and cutters is shown in Figs. 24, 25, and 26, Plates 51 to 53, of which three are in service and some fifty more building. They are exceedingly simple, the turbine comprising a single reentry

wheel with reversing buckets cut in the shrouds of the ahead blades. The complete turbine and gear, including maneuvering valve, weighs 4,100 pounds for a 600-horse-power outfit. The steam consumption with 330 pounds steam pressure and 27-inch vacuum is 14.9 pounds per shaft horse-power hour at 600 horse-power by actual test. The reversing element is effective. On actual trial the boat was brought stationary in the water in its own length from full speed ahead.

Concerning steam turbine details that differ from land practice because of their application to ships, there are the following—

GOVERNING ARRANGEMENTS.

With the old reciprocating engines, racing in heavy weather was always to be reckoned with. While governing arrangements were sometimes furnished by the builder, they usually passed most of their existence in a store-room locker. While the reciprocator may accelerate rapidly, it may generally run at proportionately higher relative speeds than the turbine without injury.

With the direct-connected turbine, governors used always to be fitted, but were subsequently found to be of no particular value because the small diameter high-speed propellers always being given the maximum submergence seldom came out of water with the vessel pitching. With the geared turbine the propeller dimensions revert to that of the reciprocating engine, and while because of its inertia the turbine and gear may accelerate less rapidly than the reciprocator, very material increased speeds would be destructive. Therefore, a very dependable regulating mechanism is desirable which must at least have some semblance of being able to regulate and must not be a mere stop governor which on the speed reaching a predetermined limit will slam shut an automatic valve. Arrangement of governing employed by the Westinghouse Company is exhibited in Figs. 27 and 28, Plates 54 and 55.

The governor is of the ordinary fly ball type, the weights being carried on knife edges, and all working parts arranged to be under forced lubrication. The governor controls the valve shown in Fig. 28 by means of the steam relay, so that the connection between the turbine and the governor valves is merely a pipe, thus eliminating the necessity of connecting links, levers, etc. The relay may be moved by hand at any time by depressing the small spring that is above it. In this manner assurance may be obtained at any time without interfering with the operation of the vessel that the governor control valve stands ready to control should the governor weights, with a rise in speed, go to their outer position. With cross compound units both high and low-pressure elements are provided with a governor, each capable of controlling the valve, that is, either governor may reduce the flow to the turbine; or, in other words, whichever governor is running fastest will control the steam. It is usual to adjust the governor springs so that they will regulate at 10 per cent above normal speed.

Concerning the governor valve, it is of the poppet valve type and actuated by the two pistons above and below in conjunction with the spring. Both pistons have

full steam pressure at all times on their inner sides. The outer side of the upper one is open to the atmosphere. The lower side of the lower piston receives high-pressure steam through a needle valve. The lower side of the piston is also connected with the relay adjacent to the governor which will control the pressure under this piston, and hence the position of the valve.

While the regulating characteristics of this apparatus would hardly meet the rigid requirements for turbines driving dynamos, it is simple and regulates with more than sufficient accuracy for the purpose.

MANEUVERING VALVES.

An important detail, at least important to the watch engineer, is the maneuvering valve. Many shipbuilders—for economy, we presume—are content to merely furnish two throttle valves, one for ahead and the other for astern, with the possibility of admitting steam to both the ahead and astern elements at one and the same time. It has been the practice of the Westinghouse Company to furnish a maneuvering valve operated by a single hand wheel. Motion in one direction gives steam to the ahead, and in the other direction to the astern elements. The design of this valve is as shown in Fig. 29, Plate 56. An important feature is that the valves themselves are single disc, balanced valves, so that there is but a single ground seat for each valve which may easily be maintained bottle tight. They are balanced by the piston above, rendering their operation easy. With this valve mechanism the turbines are easily brought from full speed ahead to full turbine revolutions astern in twenty seconds, or vice versa.

In all cases the maneuvering valve is arranged so that it is always employed no matter what may be the valve arrangements or what the method of operation; that is, whether both turbines are operating, or only one of them in case of disablement, as shown in Fig. 5.

TURBINE GLANDS.

Most builders of marine turbines have employed a labyrinth type of packing for the turbine glands; some of them a combination of this with spring packing rings of one kind or another. There is no pretense of these glands being steam tight. To prevent ingress of air, which would interfere with the condenser performance, they are provided with a steam connection for admitting high-pressure steam for sealing so that there shall be a leakage of steam, which will do no harm, rather than one of air. It is found in practice that to absolutely preclude any air leakage there must be a superabundance of steam admitted which will blow, in considerable volumes, into the engine-room. A turbine gland used to be regarded as one of the difficult problems of design detail until in 1903 the Westinghouse Company devised what is known as the water gland. It merely comprises a centrifugal pump runner operating in a casing which, if furnished with water at the axis, would raise that water to some 10 pounds higher pressure than the maximum pressure

against which the gland is designed to pack. In service its periphery is furnished with water at some 5 pounds greater pressure than the maximum pressure at which the gland is to pack, thus providing a water annulus at the outer part of the gland, forming a hermetic seal which is very effective. For condensing turbines a water pressure of 5 pounds gauge at the periphery of the gland is satisfactory. This simple device rendered an exceedingly difficult detail one that could be forgotten, and obviously has its application to marine installations.

The design of this gland as applied to marine installations is shown in Fig. 30, Plate 57, in which there is a combination of the water gland above described for use when operating at anything above half speed, and combined therewith is a simple steam labyrinth for use when running at speeds below one-half or when standing by. This labyrinth is embryotic as compared with labyrinth glands as generally understood, and no attempt is made to have it particularly steam tight because of its being used only when maneuvering or standing by.

A reliable method of furnishing water at the proper pressure to the glands is important and easily arranged for in land installations by pumping all or a portion of the condensate to an overflow at the required elevation, or providing a tank with a float valve at this location.

For merchant ships there is usually head room enough and the condensate is usually elevated a sufficient height above the machinery to furnish the required pressure as shown in Fig. 31, Plate 58, and the system is quite automatic, requiring no adjustment.

On vessels where no head room is available, it is customary, as shown in Fig. 32, Plate 59, to provide for taking a small quantity of water from the feed line in which an orifice is provided, which will pass but little more than that required for the sealing of the glands. This water is carried to the gland system and there is provided a relief valve, by-passing the water not required back to the feed tank, thus maintaining the proper water pressure on the gland system.

The gland casings may be removed for cleaning or inspection without otherwise dismantling the turbine.

With this combined labyrinth and water gland, provision must be made to turn sealing steam on and gland water off to the gland when reducing to below half speed, and similarly to turn the steam off and the water on when accelerating above this speed. For merchant ships it is entirely satisfactory to provide two valves, one for the water, the other for the steam, located adjacent to the maneuvering valve, which may be readily manipulated by the man handling the valve. With war ships, however, which require to maneuver more frequently, an automatic valve may be provided, operated in conjunction with the turbine governor shown in Fig. 27, Plate 54. The turbine governor is provided with two springs and its travel is divided into two zones. The inner travel of the governor weights is opposed by the light spring only, the governor weights being able to compress this spring at the speed at which the gland should change over from steam sealed to water sealed. The heavy spring comes into engagement at this speed, but the governor weights are

unable to compress the two springs together until the turbine reaches the speed corresponding to which the governor should regulate the steam supply to the turbine.

Motion of the governor through the first part of its travel will, by means of the relay which it operates, either relieve or impose pressure in the chamber "X" of the gland control valve, Fig. 33, Plate 60, causing motion of the valve to either apply water or steam, or vice versa. according to whether the turbine is accelerating or retarding.

COUPLINGS.

An important detail is the turbine coupling. To permit free motion of the floating pinion frame there is a flexible shaft provided between the turbine and pinion which provides the necessary element of flexibility. The turbine and gear must be capable of axial motion relative to one another. A coupling of the type shown in Fig. 34, Plate 61, is employed. Means are provided for disassembling either turbine or gear without reference to the other, and proper provision is made for lubricating the driving pins.

ELECTRIC DRIVE.

There is much difference of opinion concerning the relative merits of gear and electric motor drive. Discussion of this important matter is refrained from here in view of certain battleship installations now being carried out. Unquestionably these installations will be entirely successful, and will fulfill all expectations, but whether the added complication, increased cost and weight of machinery, together with increased steam consumption per propeller horse-power, is warranted, can be shown only by the development of the future.

One system of electric motor drive suitable for the merchant marine has been proposed which has promise of economy greater than that hitherto attained. The proposition is to provide a number of relatively small Diesel engines whose cylinders shall not exceed a diameter of, say, 10 inches, or within the limits where absolute reliability may be expected. These would be coupled to dynamos which in turn would operate a motor driving the propeller. The locations of the engines may be where desired without reference to the propelling motor.

DISCUSSION.

The President:—This paper, No. 4, entitled "Notes on Progress in Turbine Ship Propulsion," is now before you for discussion. We will be very glad to hear from any gentlemen. It does seem as though the turbine question, and the difficulties that have come out of the turbine question through various causes, should afford an ample source of discussion of this paper, if for nothing else than for information. Is there any discussion? If not, have you anything further to add, Mr. Hodgkinson?

Mr. Francis Hodgkinson :—No, thank you, Mr. President, except to thank the Society for their kind reception of this paper.

Rear Admiral Washington L. Capps, *Vice-President:*—I think it should be understood that written communications will be in order later on, because some of the papers this year were subject to the disadvantage of not having been printed until the very last moment. The printer came to my office in Washington the other day and told me that, although all the papers were printed, he could not get them shipped by express, as the express company required an order from the War Industries Board. That indicates the added difficulty this year. These papers, it would seem, therefore, should be subject to written discussion after the meeting.

The President :—Written communications will, of course, be welcome on all the papers presented at this meeting and may be sent in after the meeting. Mr. Emmet, would you like to say something on the subject?

Mr. William L. R. Emmet, *Member of Council:*—There are one or two things in the paper that I wish to comment on. There is one interesting subject which suggests itself because of Mr. Hodgkinson's paper, and that is the question of superheat. I am making some experiments now which I think ought to be interesting, and if I get successful and useful results, I will probably report them later to this Society.

The idea is this—that in geared ship installations the steam enters the turbine in one direction, and when the ship reverses it has to go through a turbine which is operated in the opposite direction. We may imagine a ship is backing and the head turbine is going at a high speed in a certain direction. Steam is admitted to it to go in the other direction, and the turbine may continue to turn in the wrong direction for the steam going through it. Theory would indicate the production of very high temperatures under such conditions, and certain evidences which have developed have shown the existence of such high temperatures, which is an argument against the use of superheat in geared turbines. I think many of the troubles with modern turbines generally have been incident to the act of reversing. This revulsion of temperature, which occurs on highly developed surfaces, tends to produce strains in the various parts of turbines, tends to enlarge the engagement of the wheels on shaft and to introduce strains.

In the experiment referred to I am using a marine turbine arranged so that it can be run in two directions, the steam being applied in either direction.

I am putting pyrometers in the steam passages which will record instantly the temperatures produced in the act of reversing, and other conditions.

This matter is important, because it has a bearing on the relation of electric drive to gear drive, that is, in the electric drive we have one direction of rotation and can use superheat with impunity, whereas in the gear drive the use of superheat may not be so useful. The ship Mjolner, a ship of only 1,000 horse-power, used 300 degrees of superheat, and showed for a succession of voyages a performance of 38 per cent less fuel consumption than engine-driven sister ships running in the same service. That is mainly due to the use of superheat, and if such improvement is possible, we simply must have it.

There is another point I want to mention in connection with this paper. I am not going to enter into a discussion of the very difficult and complicated subject of different types of

gears, but I wish to mention that I read a paper before this Society two or three years ago on the Alquist type of gearing, and we have put on the sea a great number of ships containing that type of gearing. We have had an unconscionable amount of trouble with them, so much so that there is a general state of very serious alarm as to the matter.

However, there is always a reason for everything in engineering; the thing to do is to look for the reason, and that is what we are endeavoring to do. In this connection, there are some interesting effects of the relation of gear pressures, and in Mr. Hodgkinson's paper there is a curve showing the legitimate tooth pressures and pinion diameters. I will not take up much time with that. The point I have in mind is this—we have run these Alquist gears for some time. We have one particular case in Schenectady of a laminated gear which we have run for 1,500 hours at a pressure considerably more than double that shown by the diagram in Mr. Hodgkinson's paper, for such a pinion diameter, without the formation of a single pit, burr or abrasion of any kind, absolutely perfect glassy engagement of the tooth surfaces, showing that if you can make a thing like that and take some means by which the pressure will be equally distributed and divided, you get the result.

This Macalpine gear, of course, does that to a very great extent, and its records, I believe, are very good, as shown by Mr. Hodgkinson's paper, and also judging from what I have heard in various ways. What I have been engaged upon is another way of doing the same thing and, when it is properly applied, it works. The reason why it probably has not worked in many cases of service—although it has worked very well in some particular instances—is that it is an elastic thing, and elastic things are always liable to be subject to periodic action; that is, a thing which tends to run by a succession of bounces, in some way, due to oscillations, causes terrible strains. We have evidence of such action, and it is probably the secret of the trouble which has occurred with this type of gearing.

There are ways of restraining such movements, and these are being applied. We know that very heavy duty has been and is being done with such gears, and I simply want, as far as the present situation goes, for everybody to be patient and seek the reason for the troubles encountered.

When any troubles occur in connection with machinery, the last thing to do is to start over again. What you must do, if you have trouble with machinery, is to seek the reason. In Mr. Hodgkinson's list there is only one ship which shows more than 125,000 miles of service, but we had many ships with an equal distance to their credit before we ever knew that we were in trouble. We have a much larger number of ships on the ocean with our equipment, and they have been on the ocean a much longer period and were on the ocean long before the ships with the other classes of equipment began to appear in any large numbers. We have been turning out generators for four years driven by this type of gearing, and in a large number of cases the pressures were very heavy. We have a 100 per cent record. We never have made a renewal and never have had a broken tooth, which is a significant fact.

I am taking up your time with something a little apart from Mr. Hodgkinson's paper, because there is a very serious situation confronting the country, maybe due to the fact of the failure of these gears for which I have been responsible, and I want to say that the story is not all told. Some of them are working, and I think they are all going to work. I am not certain of it, but I think so.

The President:—Mr. Riley, will you add something to the discussion, founded on your recent experience?

Mr. R. Sanford Riley, *Member:*—Our president has called on me, no doubt, because of my position in charge of what may be called the "Trouble Department" of the Emergency Fleet Corporation. I might say that business is good in that line. (Applause.)

I appreciated very much the way Mr. Emmet spoke of the need of our study of the causes of troubles—that is what we are applying ourselves to, for with any new art you must expect a great many troubles—the art would not be worth anything if you did not encounter difficulties. You would not have an art of gearing unless you had something to overcome in its development.

We find that a great deal of our trouble lies in the lack of knowledge of those who are operating the machinery, particularly in regard to lubrication. The man who has been trained to lubricate an engine running up to 80 revolutions a minute has had a very poor training for lubricating something that runs up to between 3,000 and 4,000 revolutions a minute. It is a different matter; he has no warning whatever. Instead of the gradual heating up of a bearing, which he can test and feel with his finger and look at the kind of oil that is coming away, he is in the case of the turbine and gears dealing with something which will give scarcely any warning and which goes up in a flash, with a possibility of much damage resulting.

We have devoted ourselves to the oiling systems, and we have tried to educate the men who are operating the machinery to the need of an abundant supply of clean, cool oil. I notice, by the way, in Mr. Hodgkinson's diagram of the oiling devices that he omitted to mention one of the things we think is necessary—possibly he omitted it as being simply incidental—and that is the drain from the water side of the oil cooler. You will realize that, in the lubricating system such as is used in the reduction gearing, there is only one place where the oil and water come in close contact, and that is in the oil cooler where you have the oil separated from the water only by the cooler tubes and the heads. I suppose there is no such thing as a permanently tight oil cooler or any other device of that kind. In time they leak, due to the failure of the packing around the tubes, or possibly the failure of the tubes, so we are advocating strongly the provision of a drain from the water side. That serves two purposes. In the first place, in port it allows the draining away of the water so that the corrosion due to the presence of salt water at relatively high temperature does not cause trouble with the tubes, and it also gives an effective means of testing the apparatus to discover whether there is a leak of oil.

One thing we insist on, under operating conditions, is that the pressure of the oil—that is, the head of the oil in the oil cooler—must be higher than the head of the water on the water side. You will realize the need of that, of course. In case of a leak you have oil flowing into water, and not water flowing into the oil; it is a bad thing to lose oil, but a much worse thing to gain salt water. We have had cases of engineers, where the latter situation has existed, who had their oil level come up for some mysterious reason, and presumably they took it as a gift from the gods and allowed it to continue until something happened.

There are other things in connection with turbine gears. We now and then run across engineers who regard the collection of gears in this casing as the captain regards his chronometer—something which must not be monkeyed with. We are trying to get the engineers to take off the covers and become familiar with what there is on the inside.

I do not think of anything else of special interest applying to the paper, but I am glad to have an opportunity to speak of the need of education of engineers who have charge of these reduction gears.

Mr. Howard C. Higgins, *Member of Council:*—The author makes a statement regarding the feed water heating which is misleading. He says: "With the advent of turbine-driven auxiliaries and electrically operated winches, etc., the auxiliary exhaust may be uncontaminated with oil, permitting the employment of an open heater for shipboard use, and a more complete separation of air from the feed water," and refers to this open heater as being similar to the jet condenser. I think heaters of that kind, the jet condenser style, were in use in marine practice before the tube heater which we now use. The Weir heater is an open heater; the steam comes in contact with the feed water. He says further, with regard to the economy of the open heater, that there is no advance in economy in operation beyond the economy secured by the use of the closed heater. That is probably true, but you save money in the cost of the heater, and it necessitates no pump. He further says:—"Such a type of feed heater eliminates need of a separate feed tank and must be located some feet above the feed pumps to preclude the latter being vapor bound because of pumping water near the temperature of evaporation." Of course we can appreciate that some feet may be considered a few feet. The Weir heater is located about 20 feet above the pump, which necessitates additional piping and additional expense. The open heater may not give as much temperature, in some cases, as the closed heater. The greatest temperature I have ever seen on an open heater is about 220 degrees, while 240 degrees can be obtained with a closed heater used with the exhaust steam on board ship. You can also obtain within about 12 or 15 degrees the temperature of the feed water of the actual temperature in the steam, which is not a great loss to pay for the advantages of the closed heater.

The President:—Professor Sadler, have you anything to say?

Professor Herbert C. Sadler, *Member of Council:*—I regret, Mr. President, I have not had an opportunity of reading the paper. It just came into my hands this morning, and I would like to have permission to communicate some comments on the paper later.

I would like, however, to draw attention to one fact, and that is that we are facing somewhat of a serious situation in connection with geared turbines. I think the general opinion to-day is that we ought to be a little careful before adopting geared turbines for cargo vessels. I for one am always anxious to see advances made in engineering, and I have the feeling that we, all of us, have got to do whatever we can to make the geared units we have on board our ships a success. They may not be the final solution of the problem, but we have taken a step in advance by adopting the geared turbine to a large extent in our modern cargo vessels and although we may have had some failures, I sincerely hope that we can, and I think we can, find out the cause of these failures. Certainly every one connected with this Society should take an interest in this matter and do what he can to make this installation a success.

Mr. N. W. Akimoff, *Visitor:*—It would be of great interest to all present to know Mr. Emmet's opinion on the subject of torsional vibration. It is a well-known fact that a shaft, bearing on both ends heavy objects, such as, say, a propeller on one end and a large reduction gear on the other, will possess a rather low period of torsional oscillation, the amplitude of which may be quite considerable. I remember in my own experience in a high grade motor car, built in this country, it had a seven-bearing shaft and had all the parts balanced, and yet there was a tremendous vibration, which apparently came from the priming

gears. Nothing could remedy that until a Lanchester damper was put on, about 5½ or 6 inches in diameter, after which all the trouble immediately disappeared.

The trouble in that case was apparently due to the fact that it was a seven-bearing and not a three-bearing shaft, because in a three-bearing shaft the torsional vibrations would be of a higher period and would not interfere. In the seven-bearing shaft the period is low, being about 1,400 revolutions, and it was immediately and entirely chocked by the Lanchester damper.

I would like to know what has been done so far to ascertain that the failure of the geared drive is not due to this torsional vibration. Should this actually be the fact, the natural remedy would probably be in applying some frictional device similar to the Lanchester damper in practically the same way as described above. Of course a great deal of vibration may be due to sloppy balance. It then can be remedied only by careful balancing, but in regard to torsional vibrations it is of importance, first, to establish their presence, numerically, and then to take them out. Can Mr. Emmet give us any information on that subject?

Mr. Emmet:—In reply to Mr. Akimoff's question, I cannot say whether torsional vibrations of shafts do or do not play a part in these gearing difficulties. Very marked differences have been observed between conditions in ships in which the machinery is forward and those in which the machinery is near to the propellers. With gears of the Alquist type in which the engagement between gear and pinion is a flexible, or, so to speak, an elastically compressible one, it would seem possible that torsional vibration might be a contributing factor which has not yet been considered or observed. If such torsional vibration was discovered in propeller shafts connected to Alquist gearing, a cure might be somewhat inconvenient, but I feel sure that it would be possible.

Mr. Ernest H. B. Anderson, *Member* (Communicated):—This paper is of special interest to the members of the Society, largely for the reason that this form of ship propulsion is at the present time receiving a great deal of criticism owing to breakdowns, most of which have taken place in the gearing, rather than with the turbines.

A feature of the paper appears to show that geared turbine marine installations can only be a success provided that gears are built having a patented device which is manufactured solely by the company with whom the author is associated.

The author refers particularly to Sir Charles A. Parsons exploiting a design of gear in 1910 which has rigid bearings, and it may be of interest to add that this so-called exploit is to-day the pioneer mechanical reduction gear installation for a very large fleet of vessels consisting of freighters, passenger vessels, transatlantic liners, cross channel craft, and for every type of war vessel afloat.

On the other hand, no marine development of geared turbine installations took place in this country until 1915. In the summer of this year (1915) the U. S. T. B. D. Wadsworth completed official trials and was placed in commission. This vessel was built and engined by Bath Iron Works, Ltd., of Bath, Maine, and the ship now stands first in the Navy as regards economy of fuel for propelling purposes, reliability in service and saving of machinery weights.

Further, it was this vessel that led the first flotilla of American destroyers that crossed the Atlantic in May, 1917.

Plate 31 shows curves, giving particulars of gear tooth pressures in relation to pinion di-

ameter. Dealing with the curve for floating frame gears, it is of interest to note that the author does not give particulars of any installations having pinions greater than 11 inches diameter. Further, it seems to me that the point representing a "22,000 S. H. P. gear" is hardly correct, my first impressions being that this S. H. P. was delivered by one pinion, whereas calculations show pretty conclusively that this large power was delivered by four pinions.

Further, I hope the author will perhaps see his way to give tooth-pressure loads for gears having pinions greater than 11 inches diameter, or state definitely that the extension of the curve up to 20 inches diameter represents estimated figures rather than actual results.

The curves of rigid bearing gears are of special interest, but it is somewhat unfortunate that the author does not definitely state just whose practice they represent, because you immediately get the impression that the curves are directly comparable in every way. If the author tabulated the data from which he made those curves, then I wish to state that he did and does fully realize that these curves cannot be compared on an equal basis with his curve.

On the other hand, if these curves were given to him by correspondents abroad, then I am equally positive that they were never intended to be used for the purpose of exploitation.

Mr. Macalpine in a recent paper stated that all gears built with the floating frame had teeth cut with 30 degrees helical angle, and I believe the circular pitch is about 0.90 inch, whereas most of the British gears have been cut with about 45 degrees helical angle and circular pitch about 0.78 inch.

Any such gear having 45 degrees helical angle cannot be compared on an equal basis with one having 30 degrees, and to make the matter clearer I quote Mr. McAlpine's own words:—*

"In floating frame gears a helical angle of 30 degrees has always been used. This brings sufficient teeth into contact at one time to secure smooth and quiet running, and gives ample longitudinal forces to determine the position of the pinion. In rigid gears this angle is frequently made 45 degrees, no doubt to make these gears more quiet, but this sacrifices much strength of teeth."

Further, I believe the curves of rigid bearings are made from actual gears with pinions of all sizes up to 20 inches diameter and above, many of which have been successfully at work for five years, and any designer can use these figures with absolute safety provided that the pinion materials are of the proper quality. The curves for "floating frame" pinions should be used with the utmost caution for any sizes larger than 11 inches diameter.

The seven notes, A to G, covering the breakdowns to geared turbine installations, are specially worthy of attention, and the evidence tends to show that the maximum limit of tooth pressures is about reached, especially with the present grade of materials which can be obtained.

The necessity of having to consider using a separate oil for the gear sprays will also tend to make designers reduce tooth pressure loads.

The use of very high steam pressures and high degrees of superheat, in excess of 300 pounds and 100° superheat, will continue to present many difficulties until reliable steel castings can be freely obtained in the open market.

*Published by the Engineers' Society of Western Pennsylvania, in paper entitled "The Design and Progress of the Floating Frame Reduction Gear."

The author's paragraph dealing with maneuvering valves is interesting, for he tends to show it is a special advantage to have the turbines operated automatically rather than by brain control.

Personally, I strongly favor having separate valves for ahead and astern turbines, for it gives the operator a little more to do and makes him fix his attention on the work in hand.

The piping diagram (Plate 32), to my mind, is somewhat complicated, and I do not at all like the idea of having the shut-off valves in each pipe line, either for the high-pressure pipes or the exhaust steam lines. These valves, fitted as shown, are solely for emergency conditions, and unless they are kept in working order they are generally found useless when the unusual occasion arises.

In conclusion, it is of special interest and significance to note that the reliability of the rigid bearing type of turbine-driven mechanical reduction gearing has been firmly established. Sir Charles A. Parsons and his associates have already placed in successful operation over 7,000,000 horse-power of gears built in this manner.

Mr. Hodgkinson:—Replying to Mr. Emmet, I do not know of any troubles that have been experienced with well-designed turbines, due to them being provided with reversing elements, although there are instances of injury due to operating astern for long periods with low vacuum, when, of course, serious heat is generated in the ahead elements.

Neither have I observed, in the case of floating frame gears, with which I am most familiar, the slightest difference, so far as behavior of the machinery is concerned, whether the machinery be installed aft or amidships. I know of one tanker with machinery aft whose stern tube became injured, the shaft wearing down a total of 1⅞ inches through the wood and bronze and into the cast iron shell of the tube itself, the effect of which was to cause no disturbance whatsoever to the operation of the gear.

Concerning the use of superheat, the modern high-speed geared turbine, as pointed out in the paper, is far more sensible of operating with high superheat than was the older direct-connected drive. What is the limiting temperature with a view to both economy and reliability will, I think, be largely determined by personal judgment. The desirable amount of superheat is not necessarily less for high-speed geared turbines than for those employed for the electric drive.

Mr. Emmet refers to the S. S. Mjolner, wherein with 300 degrees superheat, 38 per cent gain in fuel consumption was observed over her sister ship, without saying anything about the machinery of the sister ship. Of course the whole of the 38 per cent was not because of superheat; there were other reasons. The S. S. Maui, for example, with but 50 degrees superheat, secured a gain of 22.8 per cent over her sister ship, her sister being a single-screw, triple-expansion reciprocator; the Maui a twin-screw steamer, each shaft driven by cross-compound geared turbines.

I am appreciative of Mr. Sanford Riley's remarks, and in the course of our work in marine installations we are indebted to both Mr. Riley and other engineers of the Technical Staff of the Fleet Corporation for their timely suggestions and co-operation. Mr. Riley refers to unavoidable leaks in coolers. There is indeed always the danger of a split tube which may admit salt water to the oil, or loss of lubricant, according to whichever element is at the higher pressure. I do not think tube packings, as ordinarily understood, should be employed. The tube should be rolled into the tube plates and proper means provided for expansion, as may readily be done.

I do not quite follow Mr. Higgins' thought in saying that should an open feed-water heater be employed there must be an additional pump. In either case there must be a pump to remove the condensate from the condenser. This can as easily deliver the water to the overhead open heater as to the feed tank, wherever it may be placed, in addition to which there must be the boiler feed pumps, none other in either case being necessary. The open-type feed-water heater is, of course, on the suction side of the feed pumps, and must, for the reasons stated, be elevated above the feed pumps.

Concerning the relative feed-water temperatures that may be obtained with the two types of heaters, this is determined entirely by the quantity and the pressure of auxiliary exhaust steam, which latter may be just as high in one case as in the other, with an advantage in favor of the open type of heater, by reason of the intimate mixing of steam and water and no dependence having to be placed upon the rate of conductivity through walls of tubes.

It is important to exclude oxygen, as far as possible, from the system in order to avoid corrosion. This plainly may be more completely carried out in the open type of heater by reason of the feed water being very close to the temperature of evaporation. With the open heater the pressure may be 5 pounds gauge and the water at 225° F., for example, and is within 3 degrees of evaporating, while with the closed heater the pressure of the water might be 300 degrees when at the same temperature it would be 200 degrees away from evaporating, under which conditions but little of the suspended air would be expelled.

Referring to Mr. Akimoff's remarks, it is not apparent what effect the number of bearings could have on the torsional vibration except perhaps one of slight dampening. In the case of the geared turbine the torque is so uniform that any variation therefrom would be of such high periodicity that any response from the torsional elasticity of the shaft would hardly be expected. Errors of balance, while productive of transverse vibrations, would not seem to be productive of torsional vibration. There is always the possibility of torsional vibration, the result of action of the propeller, but I have observed no gear trouble that I have suspected as originating from this source.

Replying to Mr. E. H. B. Anderson, I would state that he entirely misconstrues the paper if he concludes its purpose is to show that success is only to be secured with gears involving a patented device which is therein described. This is quite absurd, for rigid gearing has been successfully operated for centuries, and no advocate of the floating frame type of gear has ever suggested that any gears without this patented device could not be a success. The paper does, however, endeavor to point out that pinions of floating frame gears may be safely subjected to higher loads than those in fixed bearing gears when deflections and misalignments incidental to frail hulls must be contended with.

I think there can be no doubt but that the present great expansion in the adoption of high-speed gearing, whether for shipboard or land use, was pioneered by Melville and Macalpine. Their first large reduction gear was tested in 1909, the patents having been applied for in 1907. The results of their work was published quite generally and was common knowledge both in Europe and the United States of America at the time of the Vespasian in 1910. Sir Charles A. Parsons had experimented with gearing previous to this, but we learn from the Transactions of the Institute of Engineers and Shipbuilders in Scotland, vol. 44, page 216, that he had given up hope of success.

The curve of tooth pressures employed for floating frame gears, given in the paper, expresses a law which we believe to be quite well established, and I see no reason why it is not entirely comparable with the data which forms the curve for rigid bearing gears. The

dimension of fixed bearing gears forming the basis of the other curves are quite authentic, the data having been furnished "by correspondents abroad." Mr. Anderson is in grievous error if he supposes a breach of confidence has been committed in publishing the curves, all of which is, however, a matter of irrelevance. It would have been of interest, and more relevant, had he submitted instances, if he knew of them, of fixed bearing gears in service which regularly operate with tooth pressures different from those I have given.

Mr. Anderson is in error in his conclusions concerning the 22,000 horse-power gear. The curve is perfectly correct in this respect, the 22,000 horse-power being transmitted by two pinions and not by four, as he supposes.

Answering Mr. Anderson's question, pinions in excess of 12.3 inches pitch circle diameter have not yet been constructed. Several have been projected of larger dimensions whose diameter referred to tooth pressure would fall substantially on the curve. It was thought proper to limit the points of the curve in the paper only to gears that were in actual service.

Mr. Anderson's apparent assumption that the Westinghouse Company use practically a constant pitch of teeth is erroneous, for in all pinions there are practically a constant number of teeth, their pitch varying with the size of pinion. He refers also to the angle of helix employed by different manufacturers which vary all the way from 23 degrees to 45 degrees, the selection of which is the subject of careful consideration by the designer, who must choose an angle to secure maximum strength on the one hand, and a sufficient degree of smoothness of operation on the other. As the problem is to obtain the highest safe power per revolution per minute from a given diameter of pinion, the curves are quite comparable whatever are the details of the pitch of teeth or angle of helix.

While it is perhaps improper to discuss events which have occurred since the writing of the paper, it is of interest to state that some quite serious difficulties have been encountered with some gears being installed in cargo ships by the Westinghouse Company, these troubles having developed during manufacture and installation, and not in operation after the vessels had been placed in service. They were due, in part, to an unfortunate selection of form of involute tooth, and in part because of some execrable workmanship, the result of war-time labor conditions with a new factory and organization. Further, the stress to make delivery caused thorough shop tests to be foregone, and indeed previous experience with a large number of entirely successful gears did not indicate full-power and full-speed tests at all necessary. The whole point in referring to this matter is to state that these troubles have plainly indicated to us that floating frame gears may be designed for a much higher power constant than was hitherto thought possible, and there is no doubt that in the near future gears will be designed to operate with tooth pressures far in excess of that shown by the curve in the paper.

Mr. Anderson's supposition that it has been considered desirable to use a separate oil for the gear is of course without foundation. The author would certainly regard an installation which employed two oil systems as very undesirable.

I do not follow Mr. Anderson in his remarks concerning maneuvering valves. His preference savors to me to be borne of a desire to take the path of least resistance instead of designing apparatus to be the most adaptable. Two separate globe valves, one for ahead, and the other for astern operation, both of which may be open at the same time with unfortunate results, could hardly seem to bear comparison with a carefully designed maneuvering valve, having convenience and adaptability in view, and which precludes the above possibility. His stated reason that the two separate valves gives the operating engineer more to do does not seem to be sound.

In connection with his comments concerning the piping diagram shown in Plate 32, which permits one of the two turbines of the cross-compounds set to be quickly disconnected, the ship proceeding on its way with the other turbine, it should not be necessary to explain that ordinary gate and globe valves are quite sensible of being found in perfectly good order after long periods of desuetude.

The President:—A vote of thanks is due to Mr. Hodgkinson for his paper, which we appreciate very much. All in favor of such a vote of thanks say "Aye"; contrary-minded "No." The vote of thanks is duly given to Mr. Hodgkinson for the paper.

Mr. Hodgkinson:—I thank you, Mr. President and gentlemen.

The President:—We will now take up paper No. 5, entitled "Notes on Launching," by Mr. William Gatewood, Member.

In the absence of Mr. Gatewood, the paper will be presented in abstract by Mr. Homer L. Ferguson.

Mr. Ferguson, in presenting the paper, said:—"I will state that this paper, in essence, is the application of crushing strips between the bottom of the vessel and the sliding ways, where the heavy pressures come as the bottom of the vessel passes over the outboard end of the groundways.

"The importance of this is illustrated by the launching of a number of heavy ships, usually battleships, when deformation of the bottom occurred. That condition has been taken care of by fitting shores inside the double bottom, to prevent deformation, this shoring being carried on to the upper deck. At first it was assumed that the cause of these excessive pressures was unevenness of the ways, but later it was found out that excessive pressure over the end of the groundways was the cause, and not any unevenness in the ways at all, and that actually in launching large ships this is a more important feature than the crushing of the ship forward due to heavy fore poppet pressures in that it results in distinct damage to the vessel. To distribute these pressures, Mr. Gatewood worked up the idea of using strips carried practically throughout the length of the launching ways.

"This plan can be applied not only to large vessels, but it can be used successfully in the launching of small vessels; and I think it has another effect, in that it provides considerable elasticity of the launching ways so that any unevenness in either the ground support or groundways is automatically taken care of.

"We have recently launched a good many destroyers with pressures as low as half a ton to the square foot, and the launching has been entirely successful in every particular. The ways are provided with light crushing pieces throughout the length, and we think that the absolute uniformity of distribution of pressure which has taken place prevents any little unevennesses in the groundway from having any particular effect, and has assisted most materially in the successful launchings of these vessels. We have launched with lighter pressures than we have launched with before, and in all kinds of weather, and quite successfully."

NOTES ON LAUNCHING

By William Gatewood, Esq., Member.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

In connection with the launching of large and heavy vessels, for which launching calculations are made, two conditions of the operation usually receive especial attention:—

The pivoting pressure, or reaction on the ways when the stern begins to lift.

The minimum moment against tipping.

The calculations as usually made are well known to naval architects, and may be found described in the transactions of this and kindred societies, and in textbooks on naval architecture. The calculations assume that the level of the surface of the water is not disturbed by the entrance of the vessel, that the vessel itself remains rigid, and that the alignment of the groundways is not disturbed by the passage of the vessel. The pressures and moments obtained by the calculations must necessarily be approximations only, since the assumed conditions cannot exist in the actual launching. It is probable, however, that the results are relatively comparable, and that the calculations can be relied on with confidence in making the essential preparations for the launching.

PIVOTING PRESSURE.

Suitable provision for taking the pivoting pressure on the fore poppets was early recognized as essential, because the concentration of pressure received visual confirmation at almost every launching. It was recognized, also, that some means of distributing this pressure is necessary, as theoretically the pressure is concentrated on the extreme forward end of the sliding way. In the early days, the fore poppets were built of timbers on end, but it was soon noticed that this was not a good practice, as the compression of end grain wood is quite small compared with the compression when the grain is flat. By building up the fore poppets with the wood laid flat, an appreciable amount of compression occurs at the forward end when the vessel pivots, and the under surface of the sliding way is enabled to remain in contact with the upper surface of the groundway over an appreciable length, thus distributing the pressure between the two pairs of surfaces.

As the launching weight of vessels increased and the pivoting pressures changed from a few hundred tons to more than two thousand tons, some more definite means of distributing this pressure became necessary. The introduction in the fore poppets of a considerable depth of soft wood with grain flat seems to

have served the purpose in some cases, notably in the launching of the Lusitania and Mauretania. A special rotating device or rocker formed as a segment of a trunnion has been used successfully, as described in volume 22 of the Transactions of this Society. Curving or cambering the forward end of the fore poppet cribbing to introduce a clearance for the adjustment of the bearing surfaces has been used, as noted in the discussion on the paper above referred to. Strips of soft wood especially proportioned to crush under pressure were used in the fore poppets of certain vessels launched on the Pacific Coast, as described in volume 12 of the Transactions of this Society.

The use of crushing strips in the fore poppets seems the most simple and the most effective method of distributing the pivoting pressure, and the calculations to determine the number, size and spacing of the crushing strips are not very elaborate. It is desirable, of course, to select for the crushing strips material which is uniform in quality; and white pine, flat grain yellow pine, or Port Orford cedar would seem suitable, as fairly uniform material can be obtained and the compression curves show the proper characteristics. In Plate 62 are shown average compression curves for flat grain yellow pine and Port Orford cedar. These curves indicate that crushing begins at about 650 pounds per square inch for yellow pine and at about 750 pounds for Port Orford cedar, for which pressures the compression is less than 4 per cent, and that for a compression or crushing of 30 per cent the pressures are about 950 pounds per square inch and 1,200 pounds per square inch respectively. These curves are based on samples of width equal to or greater than their height, and the variation of pressure from the mean at 30 per cent compression was less than 10 per cent for a large number of samples, when care was taken to eliminate resiny and unseasoned yellow pine. Slightly different values were obtained when the width was less than the height.

In order to determine the most suitable arrangement of crushing strips, it is necessary to calculate the reactions and the change in grade of the keel or sliding ways for several positions after pivoting. In Plate 63 the reactions for a certain vessel are plotted in tons, and the angle between the sliding way and the groundway in inches per foot of length on base of distance slid and of length of overlap of ways. The curve of minimum mean pressure per foot run is obtained by dividing the reaction by the length of overlap of the ways, and it is evident that such pressures can only be obtained if the whole of the overlap of the ways is in bearing. They are based on a static launch, and are modified materially when the overlap is approching zero by the launching velocity of the vessel as compared with the pitching period of the vessel.

The height and general construction of the fore poppet will determine what depth of crushing strips can be fitted, and the maximum crushing in inches which can be counted on will regulate the portion of the overlap of the ways which will be in contact. If we call the reaction R, and the angle between the ways expressed in inches per foot of length as α, and the maximum crushing at the forward end of the fore poppet as C, then the length of overlap in bearing will be $C \div \alpha$, and

the mean pressure per foot run on this bearing will be $\frac{R.a}{C}$. The value of this mean pressure is plotted in Plate 63 for two values of $C-3.6$ inches and 4.5 inches, corresponding to 30 per cent compression on 12 inches and 15 inches depth of crushing strips respectively. A convenient method of determining the distribution of the crushing strips would be to take the maximum pressure as thus determined and lay it off at the after end of the overlap in bearing corresponding to the position of the vessel where this maximum occurs (17.3 feet aft of forward end of fore poppet for $C=4.5$ inches from data on Plate 63), and consider it as the pressure at which crushing should just start. At the forward end of the fore poppets lay off a pressure at which crushing should just start if, when the crushing corresponds to the value of C, the pressure is the same as the pressure laid off at the after end of the length in contact. This will be about 70 per cent of the mean pressure if flat grain yellow pine is used and 30 per cent compression is allowed in determining the value of C. When these two spots are joined by a straight line, we have the distribution of pressure at which crushing should just start to give a uniform pressure over the length of bearing when account is taken of the crushing.

It will be found that the pressures at which crushing should start for points aft of this region may be laid off to advantage the same as the highest point just determined, and for a distance aft such that the area of the pressure diagram is equal to the pivoting pressure. The diagram will show the distribution of pressures at pivoting, as a greater pressure at any point would crush the strips, and this cannot occur before there has been a change of angle due to pivoting.

The curve of maximum pressure per foot run can be obtained by laying out the distribution of pressure for intermediate positions of the vessel up to the jump off the ways, although, as previously mentioned, the excessive pressures on the tip of the fore poppets would be experienced under static conditions only. Such a curve is indicated in Plate 64. This curve shows a certain amount of crushing at points where later there is no crushing or less crushing, and the elasticity of the wood will probably enable the crushing strips to partially accommodate themselves to this condition, provided the percentage of crushing is not too great.

The pressures obtained by this method would probably be reduced somewhat by the bodily lowering of the vessel due to the crushing, unless the pivoting point assumed in the calculations corresponds to the point of no crushing.

Plate 68 is from a photograph of the fore poppets of a vessel with crushing strips arranged somewhat as described in the preceding example. The crushing strips seemed to serve their purpose admirably, distributing the reaction over the strap supports and distributing the pressures over the standing ways so that no trouble at all was experienced from the high pivoting pressures. The same arrangement was repeated for a sister vessel with similar success, the material of the crushing strips being white pine, which has about the same crushing curve as yellow pine. It will be noticed that the crushing strips are in four layers, which gives stability to the structure; and there is a further crushing of the division

boards where the crushing strips bear, which adds to the adaptability of the design to distribute the pressures.

Further refinements may be made in the calculations, if desired, to obtain full advantage of this method of distributing the pressures. On the other hand, the crushing strips are able to stand almost any amount of overloading without disintegrating, and their use cannot fail to help distribute the pressures, even if fitted without reference to any calculations at all.

WAY-END PRESSURE.

The minimum moment against tipping is primarily the measure of safety against the lifting of the fore poppets from the ways and the bodily tipping of the vessel backwards as the center of gravity of the vessel passes the end of the groundways. Many of the smaller vessels have "tipped" in launching because it was considered too expensive to extend the ways a suitable distance under water. Usually, no damage has resulted from this practice, as the pressures have been comparatively small, and the ways were so supported as to "give" appreciably during the tipping.

On larger vessels, however, even with a considerable moment against tipping, damage to the floors under the flat of the bottom has resulted, caused by the concentration of pressure over the outboard end of the groundways as the part of the vessel which was damaged passed over that spot. This concentration of pressure is not indicated directly by the calculations as usually made. Special calculations are often made, however, in an endeavor to determine these pressures. In these calculations, it is assumed that the vessel and ways do not change shape and that the distribution of reaction on the ways can be represented by the ordinates of a trapezoid, having a length equal to the overlap of the ways, an area equal to the total reaction corresponding to the particular overlap selected, and with the center of gravity of the trapezoid at the center of gravity of the reaction. If the center of gravity is nearer the end of the groundways than one-third of the overlap, the trapezoid becomes a triangle whose base is three times the distance of the center of gravity from the end of the groundways, and there is assumed to be no pressure at all at the forward end of the fore poppets. This method of determining the pressures under the bottom of a vessel was used in preparing for the launch of the Lusitania, was described in volume 12 and was illustrated in volume 22 of the Transactions of this Society.

The method of determining pressures under the bottom, above described, is based on an assumption which can hardly be realized in practice. The condition which controls would seem to be that the vessel does not remain straight, but yields to the bending forces which come into play during the launching. The natural impression which one gets of a large vessel afloat is that there is no longitudinal bending. Both theory and actual measurements, however, show that vessels are flexible beams, and records of measurements are given in our Transactions. In the

process of launching, the bending moments are quite pronounced and can be approximated with some degree of certainty, although considerably more data must be accumulated before they can be calculated with accuracy. Measurements taken during launching show the effect of these bending moments on the upper deck, as the stringers show considerable stretching during the passage of the vessel down the ways.

The effect of this bending of the vessel is to tend to concentrate the reaction of the ways prior to pivoting at two points—the outboard end of the groundways and the forward end of the fore poppets. The relative intensity of these two forces would vary to suit the center of reaction, and the sum of the two forces would be the total reaction on the ways, or land-borne weight. The reaction at the outboard end of the groundways would be a maximum before the position of minimum moment against tipping is reached, and is equal to

$$\frac{Wa - By}{l}$$

in which Wa is the moment of the weight about the forward end of the fore poppet; By is the moment of buoyancy about the forward end of the fore poppet; l is the overlap of the ways.

The settling of the ways, compression of the packing, and deformation of the bottom of the vessel all tend to distribute this way-end pressure, but it is manifestly unlikely, if not impossible, that the distribution of pressure can be as indicated by the trapezoidal formula. The use of crushing strips in the packing under the bottom has suggested itself as a means of distributing this bottom pressure, just as it has served as a satisfactory means of distributing the pivoting pressure. The calculations to determine the amount of the crushing strips required are not so simple as in the case of the fore poppet strips, but the following method would seem applicable.

From the launching calculations, determine for several positions of the vessel the reaction on the ways and the moment of this reaction about a point chosen, say 10 feet aft of the forward end of the fore poppets. Determine, as indicated in Plate 65, the length from the after end of the cradle over which a certain mean pressure per foot run must be applied to afford a reaction which will have the same moment as above described. Obtain similar lengths for other mean pressures, and plot the series of curves through the points so obtained (see Plate 66). Note the points on these curves at which the reaction at the fore poppet becomes zero, as this gives the minimum mean pressure which is practicable. The highest point of the curve joining these points of minimum mean pressure gives the maximum mean pressure which need be experienced if the crushing strips are suitably arranged.

If the strips are arranged so that they will just begin to crush at the forward end of the bearing thus determined; and if they are arranged at the after end of the bearing, over the end of groundways corresponding to this position of the vessel, so that they will give this pressure per foot run after having crushed sufficient

to permit of this length of bearing; the mean pressure per foot run over the whole length of bearing may be obtained by arranging the strips in between so that they will begin crushing at the proper pressure to give this mean pressure after crushing to suit the curvature of the vessel in this position. It is assumed in the diagram on Plate 66 that a straight line variation will prove satisfactory.

If we assume that the wedging up has adjusted the cradle so that no bending will occur to localize the pressures until after the after end of cradle has passed the end of groundways, it will be seen that in the after poppets the pressure will be not much different from the mean pressure due to the weight of the vessel. In that part of the cradle, therefore, the crushing strips can be arranged to give only a slight margin over this mean pressure, say about 25 per cent, to allow for irregularities in the strips.

The crushing strips can be arranged to give uniformly varying pressures between the after end of cradle and the outboard end of the bearing for maximum mean pressures (shown uniform in the diagram) without causing the above determined maximum mean pressure to be exceeded. Between the inboard end of this bearing and the outboard end of the fore poppet bearing, an arrangement of strips to give uniform beginning of crushing would seem satisfactory.

In order to determine with accuracy the maximum pressures over the way-end when crushing strips are fitted as above outlined, it will be necessary to calculate the deflection of the vessel in several positions and plot the pressures corresponding to the crushing and spacing of the strips, as indicated in Plate 66, to give the proper reaction and moment. The curve shown in Plate 66 represents the probable maximum pressures which will be experienced if the crushing strips are sufficiently thick to actually cause the sliding way to accommodate itself to the groundway.

In Plate 67 is shown the distribution of crushing strips which corresponds to the pressures shown on Plate 66. Four rows of 2-inch by 3-inch strips are shown in the fore poppet, one row is shown where the height is limited, and two rows amidships and aft where there is sufficient height to fit them.

One further condition needs to be mentioned. Although the crushing strips do not exert nearly as much pressure in returning to their original thickness as they do in being crushed, the recovery is appreciable, and there will be a considerable pressure exerted between the bottom of the vessel and the sliding way outboard of the end of the groundway. This pressure may be sufficient to break the sliding way if there is an appreciable crushing of the strips, as the sliding way has considerable rigidity. The excessive bending moment on the sliding way may be relieved by cambering the last few feet of the groundway.

DISCUSSION.

THE PRESIDENT:—This paper, No. 5, entitled "Notes on Launching," is now before you for discussion.

MR. E. H. RIGG, *Member:*—The question of launching ships has assumed greater importance in recent years, due to the increase in the size of ships. The Society is to be congratulated upon the fact that Mr. Gatewood has given us this interesting paper.

The question of way-end pressures is one to which the big yards have been forced to pay more and more attention, and particularly such yards as are situated here, in the neighborhood of Philadelphia, where we are, roughly speaking, 100 miles from the ocean.

We are subjected to considerable variation in height of tide at the time of launching, and although we settle the launching date to fit in with a time when high tide is to be expected, nevertheless, if the wind is in the wrong quarter, it is possible that the launching may have to be postponed. It is not exceptional to have a variation of 4 or 5 tons per square foot in way-end pressure, if you have even a foot less of tide than you expect, which condition we have found frequently in the launching calculations for battleships in this district. Mr. Gatewood's plan to eliminate elaborate internal shoring is an excellent one and, though it will need some experimentation on a small scale before trying out on a large one, I feel that the Society and the profession in general are indebted to him for his investigation and interesting presentation of the matter.

THE PRESIDENT:—Does any other gentleman wish to continue the discussion? If not, I think a motion for a vote of thanks would be in order.

MR. SPENCER MILLER, *Member of Council:*—I so move, Mr. President, that we extend a vote of thanks to Mr. Gatewood.

THE PRESIDENT:—All in favor of the motion say "Aye"; contrary-minded "No." The motion is unanimously carried.

We will now proceed to paper No. 6, entitled "Side Launchings of Ships on the Great Lakes," by Mr. Frank E. Kirby, Honorary Vice-President, and Mr. Edward Hopkins, Member. In the absence of both of the authors, the paper will be presented by Prof. Herbert C. Sadler.

Professor Sadler presented the paper and, in connection therewith, said:—

"I might say, Mr. President, that I think it is perhaps familiar to most of the members that the principal danger in a side launching is in giving the longitudinal ways too small a declivity. Provided you give a large enough declivity to the ways, there is practically little or no danger.

The reason for that is, of course, when the vessel first lands in the water she has a heel towards the water side, shortly after reaching the water, and when she picks up buoyancy, she tends to roll back towards the dock, and the danger is in her bilge catching on the edge of the dock before the vessel is bodily clear. I have seen numerous launchings, big 600-foot vessels, and as a rule there is very little, or practically no danger experienced in the launching.

SIDE LAUNCHING OF SHIPS ON THE GREAT LAKES.

By Frank E. Kirby, Esq., Honorary Vice-President, and Edward Hopkins, Esq., Member.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

With the advent of iron and steel shipbuilding on the Great Lakes, together with the fact that the location of most of the yards was not advantageous for end launching, though occasionally small vessels are launched endwise, side launching was adopted and has continued to the present day. It is receiving consideration and has been adopted in some new yards that have been established outside of the lake district.

The preparation of the ground for building ships that are to be side launched is much the same as for ships built for end launching, with the exception that the ship is on a level keel when building. This is considered by lake shipbuilders as a great advantage, not only for general accessibility, the saving of scaffolding, and blocking, but everything is plumb from the keel, which being level, no rake has to be considered.

As most of the ships are built on permanent berths, and as these berths run from 80 to 100 feet in width, this, with the inclination of the ways, usually from 1¼ inches to 1½ inches to the foot, assures a height of keel blocking from 4 to 5 feet, which gives good working room under the ship's bottom.

There are no extensive launching calculations required for side launching. The accompanying plates illustrate how uniformly the ship is borne at all periods, and the time from the releasing of the vessel until afloat is so short that no undue stress is placed upon the structure. Of course the necessary calculations for stability after launching are determined, no matter what method is adopted.

Side launching is especially adapted for repair yards where the graving dry docks are used for launching slips, as illustrated in the plan of the Toledo yards. (Plate 69.)

The methods used and arrangement of the building berths for side launching are, for all practical purposes, the same in all lake shipyards. The methods and arrangements used by the Toledo Shipbuilding Company are taken for illustrating this description, excepting that the cross-section of the building berth is of one that has reinforced concrete groundways and shoring stringers, this being the only one of the type in use by this company. The other berths used are of the usual type, with piling and timber shoring stringers and supports for the groundways, which are usually of oak or fir. They are placed between the keel blocks about 10 foot centers, extending from the inside bilge to the water's edge.

On the concrete groundways illustrated, the lower half is covered with oak

flitch 6 inches thick, forming the groundway. The upper half is of the usual size timber launching way and is hinged about the center of the berth, so that it can be dropped down until needed for launching, giving free access to the space below the ship's bottom.

The arrangement of the ways and launching tables illustrated are for a ship of 3,500 tons deadweight, of the type now building by this company for the Emergency Fleet Corporation. The dimensions of the ship are as follows:—Length overall, 261 feet; beam, 43 feet 6 inches; depth, 21 feet. The length and beam are the maximum that can go through the canals from the lakes to the sea.

While the time required for side launching is very short, the launch is much more spectacular than an end launch, there being usually a drop of from one to three feet off the end of the ways.

In a recent launching in one of the lake yards, the drop from the end of the ways to the water was only one inch less than 14 feet. No damage resulted to the hull structure.

About three weeks before the date set for a launch, the groundways are placed, and a week later the packing is placed under the ship. The triggers and daggers, two sets at each end for a ship of this size, are put in position a week before the launch, and three days before launching two patent key blocks are placed under the keel at each end, these being the last keel blocks left under the vessel, and they assist in relieving the stress on the triggers until the last moment.

The triggers are levers, two at each end, pivoted against chocks secured to the groundways. Daggers or shores extend from a point on the trigger just clear of the chocks to the ship. At the other end of the triggers, bights of rope are turned, extending back and fastened to piles or other secure anchorage. These ropes are cut with axes by men when signaled. The triggers and daggers drop away and the ship is free to move.

The signal device used consists of three vertical semaphores, shown on Plate 74, pivoted to a platform located at each end of the ship, on the lower or water side of the building berth and clear of the ship's way, in sight of each other and also in sight of the men who are to cut the ropes, holding the triggers.

About half an hour before launching, the wedging up or rallying is started; first on the upper or land side until the shores drop out, then on the lower side until the shores drop out; then again on the lower side, rolling the ship so that the keel blocks can be easily removed. The patent or key blocks, as before stated, are removed last.

The first of the semaphore signals is dropped when all the shore and keel blocks are out, the second when the key blocks are out. Usually, at this period of the operations, the ship has moved a little, which is followed up by the jack shores fitted at each end of the ship. If she has not moved, the jacks are worked until she moves. The ship is now ready to let go, and the last signal is dropped to cut the ropes, which is done simultaneously at both ends.

The data from launch of the 3,500 dead-weight-ton ship are as follows:—De-

clivity of ways, 1½ inches per foot; launching weight, 1,170 tons; area of sliding ways, 289.5 square feet; tons, weight per square foot, 4 (will go as high as 9 to 11 on large ships); time from start to leaving ways, 6.5 seconds; velocity in feet per second, 9.08 feet.

DISCUSSION.

THE PRESIDENT:—Paper No. 6, entitled "Side Launchings of Ships on the Great Lakes," is now before you for discussion. We will be very glad to hear from any gentleman on the subject.

MR. WILLIAM T. DONNELLY, *Member:*—I just would like to say a word. I had been called upon to design a side launching way myself, and I expected, when laying it down, it would be the first side launching in the South, but I found that brother Stevens was fitting out a side launching plant there. Again, the U. S. Steel Corporation, at Mobile, is building a plant with six or eight side-launching ways. I think it would be a matter of great interest to engineers who are trying to overcome the difficulties of end launching if they would investigate the side launching, not only as to how it is done, but the actual records of side launchings. I think the records show that the side launching is vastly more safe then the end launching. It certainly affords considerable basis of economy in construction, and the whole preparation for launching becomes vastly more simple.

The matter of the use of the waterfront is also something to be considered. With end launchings, the waterfront opposite the ways, or the shipyard location, is during the period of launching made inaccessible for the use of any other vessels unless the river is very wide.

Another factor of much practical importance is in the method of handling material and supplies. Much of the material can be landed on to the ship from the ground or from a floating structure. This is of considerable advantage, with access from both sides of the ship, one from land and the other from water, and it adds much to the expediting of the work in the way of delivering and handling material.

MR. ANTONIO C. PESSANO, *Member of Council:*—The paper by Messrs. Kirby and Hopkins is a very interesting one, and the authors deserve a great deal of credit for their effort to extend the practice of side launching. The paper, however, rather gives the impression that side launching is only successful in the case of small ships, such as the authors describe; but in order to remove such an impression if it prevails, I might say, for the information of the members of the Society, that we have built ships up to 14,000 deadweight tons, these ships running up to 617 feet in length and 64 feet beam, and we have launched these ships successfully sidewise.

With respect to the possibility of damage due to side launching, I think it will be of interest to the members of the Society to know that within my own knowledge, covering a period of fifteen years, I have known of at least $150,000,000 worth of ships side-launched, without any substantial claim upon the underwriters. Within the past year our own company has successfully launched over $20,000,000 worth of side-launched ships without any

claim whatsoever upon the underwriters. These facts, I think, support Mr. Donnelly's statement.

Mr. Donnelly:—At Buffalo there has recently been launched a "Laker," not only with water in the boilers but fire in the furnace, and steam up, and the vessel left the ways under her own steam.

Captain Richard M. Watt, C. C., U. S. N., *Vice-President:*—In the Navy Yard, Norfolk, we have launched several large tugs sideways. A local moving picture operator took pictures of one of the launchings and sent a copy to me, from which we figured that the heel of the ship reached 42 degrees.

Mr. Hopkins (Communicated):—The paper was not intended to give the impression that only small ships were successfully launched. The Toledo Shipbuilding Company, as well as all yards on the lakes, have successfully launched lake freighters of the largest type. The small type of ocean-going ship was being built when the paper was written and, having better illustrations on hand at this time, they were used.

The President:—Is there any further discussion? If not, I am sure that the authors of this paper, Messrs. Kirby and Hopkins, are entitled to a vote of thanks by the Society. I ask all of those in favor of such a vote of thanks to say, "Aye"; contrary-minded, "No." The vote is unanimously carried.

I wish to call your attention to several matters. The first is the banquet to-morrow night, which promises to be especially interesting.

I also call your attention to the excursion on Saturday morning, at 11.00 o'clock, in accordance with the program, for which tickets must be obtained, and if you will register your names for this excursion, so that those who are in charge may know how many are to be taken care of, the local committee will be very much obliged.

To-morrow morning at 9 o'clock there will be an exhibition of moving pictures, taken by the Submarine Boat Corporation, of launchings and other interesting features, including electric welding; also some others that will interest you.

The meeting then adjourned until Friday morning.

SECOND SESSION.

FRIDAY MORNING, NOVEMBER 15, 1918.

Preceding the opening of the session, a number of moving pictures of the plant of the Submarine Boat Corporation and other pictures were shown.

President Taylor called the meeting to order at 10.10 a.m.

THE PRESIDENT:—The moving pictures of the Submarine Boat Corporation, which you saw this morning, have so well shown the work done there that Mr. Sutphen feels that the reading of his paper No. 7, entitled, "Structural Steel Standardized Cargo Vessels," is now unnecessary, but it will appear in the Volume of Transactions.

STRUCTURAL STEEL STANDARDIZED CARGO VESSELS.

By Henry R. Sutphen, Esq., Member.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

The war has brought about a new type of ship construction, commonly referred to as "fabricated ships," which only in part describes the new method that we have had to solve in manufacturing structural steel cargo vessels at the Newark Bay shipyard.

Our problem was one of quantity production, thereby necessitating thorough standardization of design, ship material, fabrication and assembly.

By referring to the newspapers during the months of March and April, 1917, before and after we entered the war, one will note with interest how much discussion there was over the problem of new ship construction made absolutely imperative by our entrance into the great world war. Some suggested large numbers of small wooden ships of 1,600 tons burden, with high speed. Others demanded larger ships, and many agreed that wood was the only material available to construct the emergency fleet.

In the fall of 1916 the Submarine Boat Corporation had completed for the British Admiralty 550 submarine chasers which were built of wood, the hull material having been fabricated in its Bayonne, New Jersey, shops and assembled into the finished boats at Montreal and Quebec, Canada. This was the first large boat manufacturing project ever attempted and was successfully completed ahead of contract time; it was the "model experiment" for the far greater task we are now engaged in of furnishing to the United States Shipping Board Emergency Fleet Corporation one hundred and fifty 5,000-ton steel cargo ships.

Our experience in obtaining the proper quality of material for wooden boat construction, an art that had practically disappeared, made us feel certain that the large tonnage desired in wooden ships would be most difficult to obtain, not only on account of material, but also because of the shortage in wooden shipbuilding labor. Further, while wood could be fabricated into boat material, nevertheless the material would not stay put like steel, due to shrinkage, checking and rot.

Upon investigation we learned that the output of ship steel for months to come had already been allotted to the established shipyards for merchant work then under way and for naval requirements. We therefore recommended to the United States Shipping Board Emergency Fleet Corporation in April, 1917, that in place of wood we be permitted to submit a plan for manufacturing steel ships to be built with the ordinary commercial structural steel as had been employed in building our skyscrap-

ers, bridges and tanks from which America had obtained such a reputation in steel construction; and, on account of the great emergency and the demand for a large number of ships, we further suggested that we be permitted to manufacture ships and not build them one at a time.

Our plan called for utilizing the large number of bridge and structural steel shops throughout the country which were not then busy with commercial work and which could be employed in fabricating steel shapes and plates from accurate drawings and patterns which we would supply. On account of using unclassified steel, we suggested that we compete in size of ship with the then proposed wooden vessel of 3,500 tons deadweight capacity, but as we progressed in the details of design and construction it was found possible to increase the deadweight capacity and still retain standardization in design and material to 5,000 tons, which is the size of the ship we are now producing in quantity. This size was fixed for other reasons. An analysis of pre-war merchant shipping disclosed the fact that the average commercial cargo carrier ranged between 4,000 and 5,000 tons with a full-load speed of 9 knots. It was therefore believed that a 5,000-ton craft, able to make 10½ knots per hour, would be preferable and probably prove a desirable type for service in the years to come. Further, and of no less importance, careful investigation showed that the unit features of a 5,000-ton ship, fabricated at more or less distant outlying plants, would utilize freight car capacities to their fullest and most economical extent and still carry out the plan of having as many rivets as possible driven at the fabricating shops. A total of 427,000 rivets is required to be driven for one of these hulls, and of this total over 100,000 are driven at the fabricating plants, where the work is done on a much more economical basis than in the shipyard. For illustration, the smokestacks were so designed that their maximum diameter came within the width of an ordinary gondola car, permitting the stacks to be shipped completely assembled. The floors with intercostals were assembled in groups of three, the ordinary 36-foot flat or gondola car carrying six sets of floors which, when loaded, kept within the railway clearance. It was recognized at the start that the railroads would be heavily burdened and, as a very wide region would have to be drawn upon to furnish material, it was absolutely essential that the car space should be made the most of, so that the fewest possible carriers would be needed to maintain a steady flow of supplies to the assembly yard on Newark Bay.

Our problem was first to use commercial structural shapes and plates that could be had in large quantities, and design the ships so that these could be assembled with a minimum of alteration through bending, and next, that the plans should be so developed that the bridge builder and the structural shops should have no difficulty in reading the drawings and adapting their experience and equipment to the fabrication of the parts for ship construction. The naval architect had to speak and draw in terms familiar to the great army of structural steel workers, requiring some radical modifications in the matter of classification details, and imposing rather pronounced departures from the ordinary shipshaped models, in order that the materials at hand might be incorporated in the most efficient manner for maximum production and

accuracy of fit. In brief, this necessitated the elimination of curves and the substitution of straight lines and angles wherever possible.

The decks are without camber and generally without sheer, the sides throughout the length of the parallel body are perpendicular; the bottom is flat, and is merged with the sides by a short and abrupt curved bilge. By eliminating the deadrise characteristics of the vessel it was possible to adopt a uniform size of floor throughout the parallel body and to have recourse to longitudinals which would all be of the same height. Forward and aft of the parallel body the model subscribes with reasonable closeness to that of the accepted design of ocean-going carriers.

The plans accompanying this article illustrate the details of construction and contour of the vessel, which is pleasing in appearance, and from the tests made at the Government Model Experimental Basin it was disclosed that the ships are rather economical in their propulsive requirements, with a block coefficient of 0.78. Their drive is as easy as the ordinary model of cargo carrier of like displacement and similar speed. The effect of the usual sheer is obtained by giving the upper deck, forward, a flat rise of 5 feet to the stem. This, with the usual flaring bow, gives the desired measure of added buoyancy when driving into a head sea. The parallel middle body constitutes about 43 per cent of the ship's total length.

The principal dimensions and general characteristics are as follows (see Plate 81):—

Length between perpendiculars	324 feet.
Length over all, about	335 feet 6 inches.
Beam, molded	46 feet.
Depth at side to upper deck	28 feet 6 inches.
Load draught, about	22 feet 11 inches.
Number of propellers	1
Propelling engine, turbine of	1,500 horse-power,
Speed	10½ knots an hour.
Deadweight capacity	5,000 tons.

As the plans disclose, the ships are constructed upon the transverse system of framing, and the double bottom extends from the after peak bulkhead forward to the collision bulkhead. There is but one complete deck, the upper deck, extending from bow to stern. Without exception the decks are worked flat, both athwartships and fore and aft.

As quantity production was the keynote in building these ships, it was essential that the main propelling machinery should be of types capable of being manufactured in quantity. Therefore watertube boilers were chosen with reduction gear turbines. The boilers are of the Babcock & Wilcox make with a total heating surface of 5,800 square feet, operated with coal or fuel oil under natural draft. The propelling machinery consists of a geared Westinghouse turbine capable of developing 1,500 shaft horse-power, turning a 15½-foot, 4-bladed screw at 90 revolutions per minute. The turbine is connected to the propeller shaft by a helical, double reduction gear with a ratio of speed reduction of 40 to 1. The steam

consumption of the turbine when operating at full power should not exceed 12.5 pounds per shaft horse-power.

The storage capacity for fuel oil is 660 tons, carried in the double bottom, which will be sufficient to operate the vessel 7,000 miles.

The ships are fully equipped with all necessary auxiliaries and deck machinery with comfortable quarters for a crew of 60 men, including 22 men for military operations. Like all other ships building for the Emergency Fleet Corporation, the equipment is complete in every detail.

Referring to the fabrication and assembly of these ships, which undoubtedly is of the greatest interest to our members, the total weight of structural steel required for one of these ships is 1,564 tons, 462 tons being in shapes and 1,102 tons in plates. The only ship sections used in the design were a few bulb angles at both ends, amounting to 1½ per cent of the total weight, or 23 tons. Under our contract all drawings were to be approved by both the American Bureau of Shipping and Lloyd's Register. This meant that, wherever in any particular the rules of the two societies differed, we had to adopt the more stringent rule, and this resulted in a heavier ship than would have obtained by classification in one society. Notwithstanding the increase in weight between these ships and those built with ship classification steel it has been demonstrated that commercial structural shapes were used advantageously and did greatly relieve the steel mills from furnishing classification ship material.

Ninety-six per cent of the total weight of the hull was fabricated at outlying establishments. Twenty-eight steel mills supplied material to 56 fabricating plants, not to mention the contributive labors of 200 foundries, machine, pipe, joiner and equipment shops which figure more or less in the building of a cargo carrier. The fabricating shops are scattered from Wisconsin to Massachusetts and as far south as Virginia, and inasmuch as the parts are fabricated in such a large number of different shops and as the individual parts must be interchangeable, one of the first considerations was to make necessary provision for giving the information to the fabricating shops in such a manner as to insure accuracy of work and speed of production.

It was the bridge engineer working in conjunction with the naval architect who properly interpreted the details of ship fabrication into the language of the bridge shops, thereby permitting the structural shops to fabricate the complicated ship material with the tools and facilities they had in hand, an operation that many old line shipbuilders questioned could be carried out successfully. So far as the straight parts of the parallel middle body, flat tank tops and flat decks were concerned it was an easy matter. It was simply a case of making detail drawings exactly as they would be made for a railroad bridge giving definite location by dimension of every hole, rivet and each piece of steel. In all some 330 drawings were made of details of hull fabrication. From these drawings all the steel was ordered from the mills exactly to the length required. In the molded portion of the ship, however, the problem became more complicated to the bridge engineer, as this section of the shell could not

be mathematically developed. Such plates and shapes were developed full size on the mold-loft floor, reproduced on template paper, having all rivet holes punched in them on proper gauge lines and for a matter of record carefully measured up and detailed to dimension on individual drawings. Even with complete drawings it was difficult for the fabricating shops to reproduce the plates on account of the edges and gauge lines being curved. These lines could only be located by dimensioning a series of points on the curves.

As we could not count upon two men springing a batten and getting the same shape between points, we overcame this phase of the problem by sending templates of the shell plates in the molded sections to the fabricating companies. These templates, made on template paper approximately 1/32 inch thick, were direct copies of the original template developed on the mold-loft floor. A difficulty was experienced in the shrinkage and expansion of these templates and, to insure the change of shape of the templates causing no misfits, each template was marked before being sent out with certain dimensions. To begin with, the paper used is fairly heavy fabroid material, which has a rather low coefficient of expansion. It was then marked and cut in accordance with the development on the scrive board, and rivet holes, etc., were laid out upon the paper, spaced and dimensioned with great accuracy.

The correct dimension for the length of the template, also the correct dimension for width at each end, was painted on with arrows indicating exactly where these dimensions were taken. In addition to this, a straight line was scratched the full length of the template approximately at the center line. The shop receiving this template was requested, in all cases before using it, to measure it and make certain that the template, as they used it, was correct to the check dimensions given. They were also requested to test the straight line scratched on the template with a straight edge. When, as was very frequently the case, they found that the dimensions did not check or that the line was not straight, they were required to bring it to shape either by dampening it or drying it as the case might be. There still remained, of course, the possibility that when a template had been expanded by dampening and stretching, the expansion might have taken place all at one section of the plate rather than throughout its length. As it was possible for this to happen, neither checking the dimensions on the template nor checking the straight line would detect the error. To overcome this we insisted that the fabricator check their templates against the detailed drawings which were furnished them. Inasmuch as the local steel tapes determined the measure of this variation, it was of prime importance that every tape at each and all of the outside works should be uniform.

A single tape was selected for the Newark Bay shipyard where the original templates and drawings were laid down on the mold-loft floor, and with this master tape every other tape to be used was compared and carefully calibrated, and a coefficient, plus or minus, prescribed in each case. In this way it has been entirely practicable to insure dimensional agreement not only within the different departments of the Newark Bay shipyard, but similarly within the different departments of every outlying contributive establishment.

This seemed a large amount of checking, but it must be remembered that in each case this had to be done only once, as the majority of shops, after getting their template exactly as required, used it to lay out one steel plate or section which was used as a template for all duplicate operations. A tolerance of 1/16 inch was allowed on all punching, this being the amount of reaming that is done when the material is being erected.

Not only is the hull material all fabricated outside but also the material for machinery installation such as piping, valves and innumerable fittings. The piping comes bent, with flanges attached, to exact shape, requiring only assembly in the ships. All joiner work and wood sheathing is fabricated in a shop at Detroit, Michigan, and shipped to the yard in complete ship sets, and as it is received completely finished, painted, varnished and with hardware attached, it is merely a matter of assembly when the ship is ready to receive it.

Before the work started, the idea of fabricating ships on such a large scale was further questioned, on the ground that the structural steel worker could not drive a tight rivet, and that his work would not be satisfactory or pass inspection. Quite the contrary has been the result, as the work has been entirely satisfactory, equal in every respect to work done in the established shipyards, although the question of labor has always been a most difficult problem and could only be obtained by a system of training which has been very thoroughly developed. Over a thousand skilled workmen a month are being turned out by our training department.

Our success is in no small part due to the layout of the shipyard. As the plan view (Plate 80) and Plates 82, 83, 84 and 85 show, there are 28 building ways, occupying a water-front space of substantially one-half mile. Electrically operated derricks, each having a maximum lifting capacity of 3 tons, are placed between alternate ways and arranged with a reach which will enable them to deal with the materials for a pair of ships. Eighteen miles of railway track insure a steady flow of steel and other material by the shortest possible routes to the points of incorporation in the ships when on the ways or at the fitting-out dock, the latter having a length of nearly one mile where 22 vessels can be berthed at one time, served by a 400-ton gantry crane with a lifting capacity of 50 tons. By an overhead structure, electric and steam cranes serve for minor lifts and place on board the ships directly from adjacent storehouses the equipment and material with the least amount of handling.

Between each companion pair of building slips and beneath the tower derricks is located an administrative building for the superintendent and foreman in charge of the two ships. Within this structure is kept a complete set of plans and all other necessary data. With the exception of the rivet forges, which have their blowers operated electrically, all of the other power tools are driven by compressed air supplied from seven direct-connected electrically operated compressor plants.

The fabricating plant at the shipyard is divided into two sections, the north and south shops, as shown on the plan (Plate 80), where bending floors are located, also punch shops, rolls and forges. The bending floors are fed from eight furnaces, all the curved sections fore and aft being bent on these floors. These shops fabricate 4

per cent of the total weight of the hull. The plates to be rolled are shipped flat from the fabricators, punched and shaped to size, and rolled at the shipyard. As many as 175 tons of plates have been rolled in a single day. Furnace plates, of which there are only eighteen, requiring hot forgings, are pressed hot in hydraulic presses at outside fabricating shops and shipped to the yard in blank form where they are punched and worked to size to correct metal templates.

Exclusive of the rolled plates, these shops with their limited equipment have delivered 460 tons of frame material per week, working night and day shifts, which, we believe, will compare most favorably with other shipyards.

Rivet driving being the barometer of production has gradually increased from 30,000 per day during July to about 75,000 a day for October, with an average drive of 32 rivets per gang hour. As the men become more experienced and accustomed to their task, we believe that a higher average hourly rate will be obtained.

For the last two months we have employed an average of about 12,000 men and have been assembling at the rate of six ships per month; 18,000 men will ultimately be required to fully man the yard, when a production of twelve ships per month may be expected.

We are a little over a year old in our enterprise, having broken ground on September 14, 1917, and during this period, through an unusually severe winter, we have completed the shipyard, delivered our first ship, the Agawam, classed A1 by both the American Bureau of Shipping and Lloyd's—this being the first fabricated ship built of structural steel to be delivered—and launched in all fifteen ships, which conclusively proves the soundness of the fabricated construction and how this method which we have employed has been the only one that could have been followed in the emergency to build the bridge of ships to Pershing and victory.

NOTE.—On actual measurement these ships have a deadweight carrying capacity of 5,350 long tons.

DISCUSSION.

THE PRESIDENT:—Mr. Sutphen is entitled to your thanks for his paper and the illustrations.

The next paper this morning is No. 8, entitled, "On Vibrations of Beams of Variable Cross-Section," by Mr. N. W. Akimoff, Member.

Mr. Akimoff presented the paper.

ON VIBRATIONS OF BEAMS OF VARIABLE CROSS-SECTION.

By N. W. Akímoff, Esq., Visitor.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

INTRODUCTION.

The object of this paper is twofold:—

1. To present a succinct review of the fundamental results of the investigations of the best known problems of vibratory motion of rods.

2. To revive the interest of research engineers in Ritz's* remarkable method, published some nine or ten years ago, but comparatively unknown in many engineering circles, especially in this country.

I. SYNOPSIS OF KNOWN RESULTS.

1. *Pendulum.*—Everyone knows the formula, $T = 2\pi\sqrt{\frac{l}{g}}$, where $g = 32.16$; l is the length (in feet) of the string or weighless rod, supporting the bob; T is the complete period (double) of the oscillations in seconds. This formula holds good only for small oscillations not over 4 degrees or 5 degrees each way. The free period of a loaded spring is expressed by the same formula, except that here instead of l we have δ, the deflection of the spring under its load (in feet). It should not be thought that the similarity of these formulae is due to the fact that δ *corresponds* to l; the true reason lies in the fact that both formulae derive from the same differential equation, except that for the loaded spring this equation is simply written down; whereas for the simple pendulum it is obtained only after we have agreed to limit ourselves to small oscillations, in view of which assumption the original equation has been simplified; otherwise it could not be solved in elementary functions. A very simple method has been proposed by the present writer (*American Machinist,* August 24, 1916) whereby the frequency of a loaded spring can be found in one setting of the slide rule. For a compound or physical pendulum, such as a swinging rod, we have a different formula: $T = 2\pi\sqrt{\frac{k^2}{gh}}$, where k is the radius of gyration about the axis of oscillation, and h is the distance between that axis and the center of

*Walther Ritz, an illustrious Swiss physicist, died in 1909 at the age of thirty-one. His works have been collected by the Swiss Physical Society and published by the well-known firm, Gauthier-Villars (Paris, 1911). They comprise a great variety of papers, all original research, relative mostly to optics and electrodynamics. Three papers are on the subject of vibratory motion; they are very difficult, but the sensation created by them was immense, and they immediately took root in the field of modern theories of elasticity. Our exposition of these methods will necessarily be of the most elementary character.

gravity of the rod. In this connection mention may be made of an interesting problem recently suggested to the writer by Admiral G. E. Burd, of the Brooklyn Navy Yard:—A rod 4.9 feet long, swinging about one of its ends, will have a frequency of 60 beats (half-oscillations) per minute. Swinging about its center of gravity, it will have a frequency = 0; somewhere between these two points the frequency has a maximum value. It is required to determine such a point and the maximum value of frequency. This problem is capable of immediate reduction to a very easy case of finding a maximum of a simple expression; the answer is that the required point is not quite 17 inches above the middle of the rod, and the greatest frequency is not quite 64.5 beats (single oscillations) per minute.

It is well to remember, in connection with all problems of pendular motion, that the period is not materially affected by damping unless the latter is excessive.

2. *Vibrating Strings.*—It will be remembered that here the displacement of any point is characterized not by the time alone, but also by the location of the point. Hence, instead of an *ordinary* we have a *partial* differential equation, very well worked out,

$$\frac{d^2y}{dt^2} = C^2\frac{d^2y}{dx^2},$$

of which the solution is usually given in two forms, trigonometric, or by arbitrary functions (see any book on differential equations). The string can be excited by either plucking or striking it with a small hammer, by bowing it, or, finally, by sounding another body near it of corresponding pitch. From one viewpoint we are interested only in the latter method, corresponding to the stationary mode of vibration, with permanent nodes (or positions of rest) and antinodes. Such a string, rigidly fixed at both ends, will have its gravest tone when it vibrates as a whole; besides this it can also be made to vibrate (either by proper mechanical excitation or by means of resonance) in any whole number of loops, with frequencies 2, 3, 4, ... times that of the fundamental tone; these tones are called overtones, or harmonics, first, second, etc. (In more rigid investigation it can be shown that overtones and harmonics do not always mean exactly the same thing, owing to the rigidity of the string.) The first harmonic will mean one node, in the middle; to the second harmonic will correspond two nodes, dividing the string into thirds, etc. As a rule a string, plucked or struck in an arbitrary manner, will not vibrate in any of such normal modes, but the general vibration will consist of a mixture of these tones. But in engineering investigations it is perfectly proper to consider these normal modes as actually taking place separately.

It is of interest to note, in this connection, the explanation of the hull vibrations as proposed by Messrs. Pollard and Dudebout, in Vol. IV of their well-known treatise, "Théorie du Navire" (Paris, 1894). According to their views, actual experience tends to show that the hull should not be considered as a vibrating rod or beam, but as a vibrating string. It is known (as will be mentioned later) that in a vibrating rod the frequencies do not follow the simple series 1 : 2 : 3 : etc., but a

much more complicated law. Yet Messrs. Pollard and Dudebout quote one authority who reports that, in a certain destroyer, the speeds at which the hull felt most sensitive were at 120, 240 and 360 revolutions per minute. They also quote Mr. Yarrow, who noticed that in a small boat such critical speeds were 200, 400, 600 and 800 revolutions per minute; while at 300, 500 and 700 revolutions per minute all vibrations ceased. Hence their conclusion that the theory of vibrating strings can be made to answer the required problem of finding such critical speeds, or at least the fundamental tone. They proposed the formula—

$$N_1 = \frac{1}{4l}\sqrt{\frac{g}{1.026}\left(\frac{M}{I}\right)_m H\left(\frac{W}{w}\right)^3}$$

vibrations per second, where—

l = length of the hull.

W = the total volume of the hull.

w = the displacement volume of the hull (unloaded).

$\left(\frac{M}{I}\right)_m$ = the average value, on half-length of ship, of the quotient $\frac{\text{bending moment}}{\text{moment of inertia}}$.

H = the extreme total height of hull considered as beam; all units are metric.

Without the slightest desire to disparage the authority of the great teachers in question, the writer regrets being quite unable to agree with such analysis, especially as regards the very premises from which they started. A hull is a beam, not a string, no matter how analyzed; and being a beam of variable cross-section, it is naturally quite difficult of handling mathematically, as will be shown later in this paper. But, and here lies the most important point, all the experiments so far quoted were made in connection with engine-driven ships, years before the advent of the steam turbine. Now the action of a reciprocating engine is in itself very rich in harmonics, which follow the series 1 : 2 : 3 : etc.; and where the third harmonic is distinctly felt, as is well known from automobile practice, for instance. So that, after all, it is not impossible that some of the vibrations were felt simply through the harmonics of the reciprocating mechanism coming into step with this or that harmonic of the free vibration of the hull. In order to justify the vibrating string theory, it would be necessary to provide a large, variable speed electric motor, with a purposely unbalanced rotor, and fed from the shore. Such a motor could be placed in various positions and various effects could be properly recorded. But, as a matter of speculation, the variable-section beam theory is much more satisfactory, as the writer hopes to show later on.

3. *Free-Free Bar.*—The gravest frequency (of transverse vibration) can be found from the following rough formula (steel):—

$$n = 60{,}000\ r/l^2,$$

where n is the frequency per second, r the radius of gyration, and l the length, both in feet. The frequencies of higher harmonics will be found from the series,

$$3^2 : 5^2 : 7^2 : 9^2 : \ldots.$$

So that, for instance, the frequency of the first harmonic will be $\frac{25}{9}$ that of the fundamental, etc. To the fundamental tone will correspond two nodes, 0.224 l from each end; the ends and the middle will, of course, be antinodes. The first harmonic (or octave) will be characterized by three nodes, one in the middle and one 0.13 l from each end. The next harmonic will have four nodes, etc. The ends will, of course, be antinodes under all circumstances. All this applies only to the rod of constant cross-section, and for this reason cannot be used for finding frequencies of so complex a structure as a hull.

4. *Clamped-Free Bar.*—The approximate formula for finding the gravest frequency (per second) of such a bar is:—

$$n = 9{,}320\ r/l^2$$

(for steel), where n, r and l denote the frequency, the radius of gyration and the length (both in feet). The frequency of the next harmonic will be 6.25 times greater; that of the following harmonic will be 17.6 times greater than that of the fundamental, etc.

Vibrating in the fundamental tone, the rod will, of course, have one node, where clamped, and the free end will be antinode. In the next harmonic there will be an additional node, 0.226 l from the free end. In the next harmonic there will be two such nodes, one 0.132 l away from the free end and the other almost exactly at the middle; etc.

5. *Supported-Supported Bar.*—The fundamental frequency can be given by the formula:—

$$n = 26{,}400\ r/l^2,$$

the notations being the same as before.

The frequency of the first harmonic is four times and of the second nine times higher than that of the fundamental.

Vibrating in the gravest node, the rod has no nodes between the ends; to the first harmonic there will correspond one node, in the middle; the second harmonic will be characterized by two nodes, dividing the length into thirds, etc.

6. *Clamped-Clamped Bar.*—Its frequencies are the same as those of the free-free bar.

General remark.—The frequencies (and therefore the periods) and the nodes of all these bars are found in a perfectly uniform manner from the same partial differential equation:—

$$\frac{d^2y}{dt^2} + a^2\frac{d^4y}{dx^4} = 0.$$

The methods of solution will be found in Lord Rayleigh's "Theory of Sound," or in St. Venant's "L'Elasticité des Corps Solides," and it will be at once apparent that the difficulty lies not in the work of finding the general solution itself, but in adjusting the arbitrary constants to fit the special conditions of each problem, such as tension, bending moment, or shear at the ends, etc.

7. *Longitudinal and Torsional Vibrations.*—While we are not immediately interested in these, for the sake of ready reference the rough formulae are given for corresponding frequencies (steel):—

Longitudinal: $n = 8400/l$ (l being the length in feet)
Torsional: $n = 5300/l$ (l being the length in feet)

These nodes will be characterized by one node in the middle; the first harmonic will have two nodes and twice the frequency; the second harmonic will have three nodes and three times the frequency of the fundamental; etc.

8. *Compounding of Vibrations.*—As a general rule a vibration taken at random is a mixture of the fundamental with several harmonics. Prof. D. C. Miller's delightful book, "Science of Musical Sounds," contains not only a complete bibliography of this subject, but also many instructive diagrams with clear explanations by which any engineer would profit immensely. Any compound vibration can be decomposed by analysis, or by means of special instruments, into its primary elements (so-called normal modes), fundamental and overtones. Now if there is any disturbing periodic force (such as an unbalanced engine), and if its period happens to be the same (or nearly so) as that of one of the normal modes of the free vibration, we have synchronism, where the effect is generally quite out of proportion to the magnitude of the disturbing force. For instance, the vibration due to a reciprocating engine is compounded of the fundamental, the first harmonic (of double frequency) and of the second harmonic (of three times the frequency of the fundamental); higher harmonics, as a rule, are not felt. Now if any one of these frequencies is the same as any of the natural frequencies of the structure, its effect will be felt in a marked degree.

The reader, unfamiliar with elastic vibrations in general, is advised to carefully study the fourteenth chapter of Morley's excellent book, "Strength of Materials," where many useful formulae will be found.

II. MORROW'S METHOD.

1. A very interesting method for finding periods of vibrating bars has been proposed by Professor Morrow of Bristol, England.* The essential features of this method are as follows. By assuming an equation which completely satisfies the end conditions, we can find both the vibration curve and the period of the fundamental to any required degree of accuracy. Initially, the method gives too small a value of frequency, which improves with further steps. When the density and flexural rigidity of the bar are variable from point to point in its length, the finding of periods by ordinary methods of analysis is often a problem of utmost difficulty; while the method proposed by Professor Morrow leads to much easier solution. The main principle lies in the fact that if a bar is vibrating so that every point in it has the same period (in other words, in one of its normal modes) then the ratio of the acceleration to the displacement is constant for all points.

Phil. Mag., 1905, pp. 113-125.

If, for instance, y_z be the displacement at a distance z from the point chosen as origin, so that $\frac{d^2 y_z}{d t^2}$ is the acceleration, and if y_1 be the displacement of any chosen point (say that at which the displacement is a maximum) then the above statement may be expressed by the equation:—

$$\frac{d^2 y_z}{d t^2} \Big/ y_z = \frac{d^2 y_1}{d t^2} \Big/ y_1 \text{ or simply, } y''_z = \frac{y''_1}{y_1} y_z \tag{1}$$

This, of course, will be instantly recognized as the general equation of vibratory motion, $d^2y/dt^2 = -a^2y$, of which the frequency is $= \frac{a}{2\pi}$ or the period is $= \frac{2\pi}{a}$. On the other hand, we know the expression $M = EJ/\rho$ connecting the bending moment, the moment of inertia of the cross-section, and the radius of curvature at the section in question. This is often given in a differential form (assuming that the radius is very nearly $= 1 \Big/ \frac{d^2y}{dx^2}\Big)$

$$M = EJ \frac{d^2 y}{dx^2} \tag{2}$$

In a freely vibrating beam or bar the moment M is the restoring agency; in other words, a couple due to reversed effective forces of extension and compression, acting in any cross-section according to the well-known straight line theory; E, of course, is the modulus of elasticity, and J is the moment of inertia, about the neutral axis of the cross-section. Now, since the moment M is a function of the mass per unit length, of the end forces, and of the accelerations, we can express it in terms of $\frac{y''_1}{y_1} y_z$ and the density and cross-sectional area of the bar. And assuming for y_z a hypothetical type of vibration, satisfying the end conditions, we can insert the value of M thus obtained in the equation (2). Solving for y we have a second approximation to the center line of the bar, and the period can be calculated as

$$T = 2\pi \sqrt{-\frac{y_1}{y''_1}} \tag{3}$$

The value of y just found can now be substituted into (2) and a closer approximation secured by solving the results, as will presently be illustrated. Professor Morrow's paper should be carefully studied in detail; but for our immediate purpose we shall take only the following examples:—

2. *Clamped-Free Bar.*—Let the origin be at the free end of the bar, whose length is l, the area of cross-section being a and the density of the metal being γ By D'Alembert's principle the acting forces are in equilibrium with the inertia forces. Now the moment of the inertia forces about some section X (distant x from the origin) is the sum of infinitely small products:—mass times acceleration times leverage,

$$\int_0 \gamma\, a\, y''_z\, (x-z)\, dz\,;$$

So that the differential equation of motion (of the center of each section will be—

$$-\frac{d^2y}{dx^2} = \frac{a\gamma}{EJ}\frac{y_1''}{y_1}\int_0^x y_z(x-z)\,dz \tag{4}$$

where $a\gamma$ can be taken from under the integral sign only where both a and γ are constant throughout the length.

If now we succeed in finding the solution for y, from this equation, in ascending powers of x, we can readily find the period of the vibration.

Let us assume a value of y_z such that it satisfies the end conditions. For instance, let

$$y = A + Bx + Cx^2 + Dx^3 + Ex^4,$$

At the free end, where $x = 0$, we have $y = y_1$ (let this amplitude of the end be any); then $A = y_1$ (by making, in above equation, $x = 0$); also $d^2y/dx^2 = 0$ (because the bending moment is here $= 0$); and $d^3y/dx^3 = 0$ (because the shear at the free end is $= 0$); hence, $C = 0$ and $D = 0$. On the other hand, at the fixed end, where $x = l$, we have $y = 0$ and $dy/dx = 0$ (the elastic line is tangent to its neutral position); so that

$$B = -\frac{4}{3}\frac{y_1}{l} \text{ and } E = \frac{y_1}{3l^4}$$

So that the assumed equation, corrected for the end conditions, becomes

$$y = y_1\left(1 - \frac{4}{3}\frac{x}{l} + \frac{1}{3}\frac{x^4}{l^4}\right) \tag{5}$$

(*Important note*: The reader's attention is called first to the manner of handling the end conditions, which is of greatest importance in our last chapter; and, second, in the fact that the degree of the assumed equation must be fourth; it is easy enough to see that nothing else would answer; the other examples of Professor Morrow's method call for different degrees of the assumed expression for y, such as fifth or sixth.)

Since, then, we now have the general expression of the ordinate y (or y_z) in function of any arbitrary ordinate y_1 (say the amplitude of the free end), let us substitute it for y_z in equation (4).

$$-\frac{d^2y}{dx^2} = \frac{a\gamma}{EJ}y_1''\int_0^x\left(1 - \frac{4}{3}\frac{z}{l} + \frac{1}{3}\frac{z^4}{l^4}\right)(x-z)\,dz$$

$$= \frac{a\gamma}{EJ}y_1''\left(.5x^2 - .2\frac{x^3}{l} + .01\frac{x^6}{l^4}\right)..$$

Integrating twice, each time adjusting the constants of integration to suit the end condition, we have—

$$-y = \frac{a\gamma}{EJ}y_1''\left(.08194\,l^4 - .112698\,l^3 + .0416\,x^4 - .01\frac{x^5}{l} + .000198\frac{x^8}{l^4}\right) \tag{6}$$

which is approximately the vibration curve and, for the free end, gives

$$-y_1 = .08194\frac{a\gamma l^4}{EJ}y_1'' \tag{7}$$

which is the general equation of pendular motion, the frequency being very nearly that given in Chapter I.

In order to get a still better approximation we can insert for y_z, in (4), the value of y just found in equation (6), and using the value just obtained, (7), for y_1, whence—

$$-\frac{d^2y}{dx^2} = \frac{12.2\,a\gamma}{EJl^4}\,y_1'' \int_0^x \Big(.08164\,l^4 - .112698\,l^3 z + .0416\,z^4$$

$$-.01\frac{z^5}{l} + .000198\frac{z^8}{l^4}\Big)\,(x-z)\,dz$$

$$= \frac{12.2\,a\gamma}{EJl^4}\,y_1''\Big(.04097\,l^4x^2 - .018783\,l^3x^3 + .00138\,x^6$$

$$-.000264\frac{x^7}{l} + .000002\frac{x^{10}}{l^4}\Big)$$

or, integrating,

$$-y = \frac{.122\,a\gamma}{EJl^4}\,y_1''\Big(.663084\,l^8 - .912718\,l^7x + .341435\,l^4x^4$$

$$-.093915\,l^3x^5 + .00248\,x^8 - .000367\frac{x^9}{l} + .000002\frac{x^{12}}{l^4}\Big).$$

Thus the vibration of the free end (where $x = 0$) becomes—

$$-y_1 = .0809227\frac{a\gamma l^4}{EJ}\,y_1''$$

whence the frequency—

$$n = \frac{3\cdot5153\,r}{2\pi l^2}\sqrt{\frac{E}{\gamma}},$$

which is still nearer its true value, although the difference is not great.

3. *Free-Free Bar.*—If both ends are free, and there are no external forces acting on the bar, the end conditions at both ends are the same—

$$y = y_1 \qquad \frac{d^2y}{dx^2} = 0 \qquad \frac{d^3y}{dx^3} = 0$$

In other words, the extreme deflection is that value, y_1, in function of which we will express the elastic line; furthermore, at the ends there is no bending moment; and no shear. Assuming the deflection to be given in function of the ordinate by some such equation as—

$$y = A + Bx + Cx^2 + Dx^3 + Ex^4 + Fx^5 + Gx^6,$$

we can readily see that at one end, where $x = 0$, we find $A = y_1$; also $C = D = 0$; the conditions at the other end ($x = l$) give (forming the second and third derivatives and applying ordinary rules of determinants)—

$$B = -\frac{1}{2}Gl^5 \qquad E = \frac{5}{2}Gl^2 \qquad F = -3\,Gl.$$

The value of G is found from the consideration that, since the total force on the bar vanishes, we have—

$$a\gamma \frac{y_1''}{y_1} \int_0^l y\, dx = 0 \tag{8}$$

In other words,

$$\int_0^l \left(y_1 - \frac{1}{2} Gl^5 x + \frac{5}{2} Gl^2 x^4 - 3\, Glx^5 + Gx^6\right) dx = 0$$

so that—

$$G = \frac{28}{3} \frac{y_1}{l^6},$$

therefore the equation assumed for y becomes—

$$y = y_1 \left(1 - \frac{14}{3}\frac{x}{l} + \frac{70}{3}\frac{x^4}{l^4} - 28\frac{x^5}{l^5} + \frac{28}{3}\frac{x^6}{l^6}\right).$$

Substituting this for y in equation (2),

$$-\frac{d^2y}{dx^2} = \frac{a\gamma}{EJ}\frac{y_1''}{y_1}\int_0^x y_z (x-z)\, dz,$$

we have

$$-\frac{d^2y}{dx^2} = \frac{a\gamma}{EJ} y_1'' \int_0^x \left(1 - \frac{14}{3}\frac{z}{l} + \frac{70}{3}\frac{z^4}{l^4} - 28\frac{z^5}{l^5} + \frac{28}{3}\frac{z^6}{l^6}\right)(x-z)\, dz$$

$$= \frac{a\gamma}{EJ} y_1'' \left(.5x^2 - .7\frac{x^3}{l} + .7\frac{x^6}{l^4} - .6\frac{x^7}{l^5} - .16\frac{x^8}{l^6}\right).$$

Integrating twice and evaluating the second constant by reference to (8) we have—

$$-y = \frac{a\gamma}{EJ} y_1'' \left(.001993\, l^4 - .00925\, l^3 x + .0416\, x^4 - .038\frac{x^5}{l}\right.$$
$$\left. + .0138\frac{x^8}{l^4} - .00925\frac{x^9}{l^5} + .00185\frac{x^{10}}{l^6}\right)$$

whence the frequency—

$$n = \frac{22.4}{2\pi}\frac{r}{l^2}\sqrt{\frac{E}{\gamma}}$$

which is very near the value given in Chapter I.

In this paper we are especially interested in beams of variable cross-section. For this reason the following three examples, worked out by Professor Morrow, should be studied with greatest care:—

4. *Clamped-Free Bar of Varying Breadth* ($b = Ax$).

Let the depth h be constant. Our equation (4) will then become

$$-\frac{d^2y}{dx^2} = \frac{1}{EJ}\int_0^x \gamma a_z y_z' (x-z)\, dz \tag{4}$$

or, by virtue of (5) and considering that $a_z = Ahz$; also that $J = \frac{bh^3}{12}$,

$$-\frac{d^2y}{dx^2} = \frac{2\gamma y_1''}{Eh^2}\left(x^2 - \frac{2}{3}\frac{x^3}{l} + \frac{1}{21}\frac{x^6}{l^4}\right).$$

Integrating twice, we have

$$-y = \frac{2\gamma y_1''}{Eh^2}\left(.122619\, l^4 - .173469\, l^3 x + .083\, x^4 - .03\frac{x^5}{l} + .000850\frac{x^8}{l^4}\right.$$

Hence the amplitude of the free end ($x = 0$) is given by

$$-\frac{y_1''}{y_1} = 4.07767\frac{Eh^2}{\gamma l^4}$$

In order to find a better approximation, both these equations are substituted into (4_1) in the usual manner, with the result—

$$-\frac{d^2y}{dx^2} = \frac{97.86408\gamma}{Eh^2l^4}\, y_1''\left(.020436\, l^4 x^2 - .014455\, l^3 x^3\right.$$
$$\left. + .001984\, x^6 - .000595\frac{x^7}{l} + .000007\frac{x^{10}}{l^4}\right)$$

or, integrating twice,

$$-y = \frac{.9786408}{Eh^2 l^4}\gamma y_1''\left(.240053\, l^8 - .3408\, l^7 x + .170304\, l^4 x^4\right.$$
$$\left. - .072279\, l^3 x^5 + .003543\, x^8 - 000827\frac{x^9}{l} + 000006\frac{x^{12}}{l^4}\right)$$

whence the amplitude of the free end, by—

$$-\frac{y_1''}{y_1} = 4.256\frac{Eh^2}{\gamma l^4},$$

and its frequency—

$$n = \frac{2.063h}{2\pi l^2}\sqrt{\frac{E}{\gamma}}.$$

In other words, all clamped-free bars of which the depth is constant and the breadth proportional to the distance from the free end will vibrate with a period quite independent of the breadth of the fixed end (hence of the value of A).

5. *Clamped-Free Bar of Varying Breadth* ($b = Ax^2$), the depth being constant and $= h$. Here—

$$-\frac{d^2y}{dx^2} = \frac{12\gamma}{Eh^2x^2}\frac{y_1''}{y_1}\int_0^x z^2(x-z)\, y_z\, dz \qquad (4_{11})$$
$$= \frac{\gamma y_1''}{Eh^2}\left(x^2 - .8\frac{x^3}{l} + .071428\frac{x^6}{l^4}\right),$$

(by substituting the tentative curve from (5)). Integrating twice,

$$-y = \frac{\gamma y_1''}{Eh^2}\left(.098928\, l^4 - .143537\, l^3 x + .083\, x^4 - .04\frac{x^5}{l} + .001275\frac{x^8}{l^4}\right),$$

whence the expression of the end amplitude—

$$-\frac{y_1''}{y_1} = 10.1083\frac{Eh^2}{\gamma l^4}.$$

Instead of finding the frequency we shall try the next approximation by substituting the last two equations into (4), as usual,

$$-\frac{d^2y}{dx^2} = \frac{121.3\,\gamma y_1''}{Eh^2 l^4 x^2}\int_0^x z^2(x-z)\left(.098928\,l^4 - .143537\,l^3 z\right.$$

$$\left. + .083\,z^4 - .04\,\frac{z^5}{l} + .001275\,\frac{x^8}{l^4}\right)dz$$

$$= \frac{.1213\,\gamma y_1''}{Eh^2 l^4}\left(8.24405\,l^4 x^2 - 7.17687\,l^3 x^3 + 1.48809\,x^6\right.$$

$$\left. - .5\,\frac{x^7}{l} + .00966\,\frac{x^{10}}{l^4}\right).$$

Integrating twice,

$$-y = \frac{.1213\,\gamma y_1''}{Eh^2 l^4}\left(.75074\,l^8 - 1.09782\,l^7 x + .687\,l^4 x^4 - .35884\,l^3 x^5\right.$$

$$\left. + .02657\,x^8 - .00772\,\frac{x^9}{l} + .00007\,\frac{x^{12}}{l^4}\right),$$

hence the end amplitude, through

$$-\frac{y_1''}{y_1} = 10.9812\,\frac{Eh^2}{\gamma l^4},$$

and its frequency—

$$n = \frac{3.313\,h}{2\pi l^2}\sqrt{\frac{E}{\gamma}}.$$

A third approximation carried out precisely in the same manner would result in the end amplitude through the equation—

$$-\frac{y_1''}{y_1} = 11.063\,\frac{Eh^2}{\gamma l^4},$$

and its frequency—

$$n = \frac{3.326\,h}{2\pi l^2}\sqrt{\frac{E}{\gamma}},$$

where, again, the breadth of the bar does not enter.

6. *Clamped-Free Bar of Varying Depth* ($h = Ax$), the breadth, b, being constant.

The exact form of the equation, says Professor Morrow, first assumed for the type of vibration, is immaterial to the final result; but, by choosing a suitable equation, the labor involved in obtaining this result to any required degree of accuracy is reduced.

In the present case Professor Morrow recommends, instead of (5), the form—

$$y = y_1\left(1 - \frac{2x}{l} + \frac{x^2}{l^2}\right),$$

which, inserted in—

$$-\frac{d^2y}{dx^2}=\frac{12\gamma}{EbA^3x^3}\cdot\frac{y_1''}{y_1}\int_0^x bAz(x-z)\,y_z\,dz \qquad (4_{\text{III}})$$

gives—

$$-\frac{d^2y}{dx^2}=\frac{\gamma y_1''}{EA^2}\left(2-\frac{2x}{l}+.6\frac{x^2}{l^2}\right);$$

integrating twice, we have—

$$-y=\frac{\gamma y_1''}{EA^2}\left(.483\,l^2-1.2\,lx+x^2-.3\frac{x^3}{l}+.05\frac{x^4}{l^2}\right)$$

and the equation of the end amplitude ($x=0$)—

$$-\frac{y_1''}{y_1}=2.07\frac{EA^2}{\gamma l^2}.$$

In the second approximation, carried out in the usual manner, this becomes—

$$-\frac{y_1''}{y_1}=2.312\frac{EA^2}{\gamma l^2},$$

and in the third approximation—

$$-\frac{y_1''}{y_1}=2.3445\frac{EA^2}{\gamma l^2},$$

with the frequency—

$$n=\frac{1.5312}{2\pi}\frac{A}{l}\sqrt{\frac{E}{\gamma}},$$

so that here the period is independent of the breadth, but the influence of the depth is exhibited by means of the constant A.

7. *Review.*—It will thus be seen that Professor Morrow's method is not nearly so difficult as it appears; the integrations to be performed are of the most elementary nature, and the method itself is perfectly uniform. The order of procedure is as follows:—

(*a*) Bearing in mind the obvious relations (1) and (2), form the equation (4).

(*b*) In this substitute a tentative equation of the form (5), satisfying the end conditions, not neglecting to change x for z, when placing (5) under the integral sign (x being here not a variable but a limit of integration).

(*c*) Multiply by dx and integrate; multiply the result by dx and integrate again, finding each of the constants of integration through the end conditions.

(*d*) The result will be the approximate vibration curves. Make $x=0$, in it, and the result will be an equation of the vibration of the end, of the usual kind, $y''=-a^2y$; hence the frequency $n=a/2\pi$.

(*e*) For the next approximation, substitute the last two equations, in (4), in the following manner:—Place y, just found, for y_z under the integral sign, and the value $y''/y=-a^2$, before the integral sign and perform the integration.

(f) The result will be again an easy differential equation of second order. Integrating it we have a better approximation for the curve. Placing $x = 0$ in the result we again have an equation of the end amplitude of the form $y'' = -b^2y$. Hence the desired frequency $u = b/2\pi$.

8. *Slocum's Formula.*—Those interested in the subject of statics of beams of variable cross-section will find much valuable information in Professor Slocum's paper "A General Formula for the Shearing Deflection of Beams of Arbitrary Cross-section, Either Variable or Constant."* Many practical examples are given as illustrations and Professor Fraenkel's formula for flexural deflection is derived from the principle of least work by applying Castigliano's theorem.

III. A FEW GENERAL PRINCIPLES.

1. *Calculus of Variations.*—The reader will greatly profit by studying Professor Byerly's little pamphlet, "Introduction to the Calculus of Variations,"† unless, of course, already familiar with the subject. For our immediate purpose only a few words will be said regarding this vast and most interesting branch of mathematical analysis.

In ordinary calculus we are often confronted with the problem of finding maximum or minimum values of a certain quantity, function of another quantity; for instance the greatest ordinate of a given curve (and, of course, the corresponding abscissa); the greatest volume of a body, whose surface is given, etc. This is done simply by equating to zero the first derivative, of the function, as to the independent variable (generally abscissa), and of finding from such an equation the corresponding value of the independent variable (say x_m). Then the value of the function, with that x_m in it, will be either maximum or minimum; in order to determine which it will be, we must find the second derivative. The negative value of the latter will mean maximum, and inversely.

But there are problems in which we are to find the *form* of a function, such that it will answer certain requirements, consisting mostly in some such condition as rendering maximum or minimum the value of a certain definite integral, involving the independent variable, the function itself, and often some of its derivatives, as well as constants. In other words, the problem of plain calculus is as follows:—Being given a certain function, $y = f(x)$, of the independent variable x, find such a value of x that y will have the greatest (or the least) of all adjoining values. The answer is a certain x_m and the corresponding $y_{max.}$ or y_{min}.

The problem of variations is quite different:—What is that form of a function, f (connecting the dependent and the independent variables in some such manner as $y = f(x)$, which will render a certain definite integral—

$$S = \int_b^a V\left(x, f, \frac{df}{dx}, \ldots\right) dx, \text{ or simply} = \int_b^a V(x, y, y', y'', \ldots)\, dx,$$

Journal of the Franklin Institute, April, 1911.

†Harvard University Press, 1917.

(where V is the functional symbol, showing how the variables are connected together), maximum or minimum, as might be the case? Will it be a straight line, $y = mx + n$, or a parabola $y^2 = 2px + c$, or a cycloid

$$y = a \cos^{-1}\frac{a-x}{a} - \sqrt{2ax - x^2}?$$

At any rate the object is always the same, to find the form of a function such that the value of a certain integral will be maximum or minimum.

Here are a few examples:—

1. Find the shortest curve between two points in a plane (which, of course, will be a straight line). Here the integral to be made minimum is simply—

$$S = \int_{x_1}^{x_2} \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\, dx$$

The integrand involves only the first derivative dy/dx.

2. Find the form of a body of revolution such that, immersed in water, it will offer the least possible head resistance to motion (Newton's problem). Here the problem hinges on the minimum value of the following integral—

$$S = \int_{x_1}^{x_2} \frac{yy'^3}{1 + y'^2}\, dx$$

(where y' is the simplified notation for dy/dx). So that the integrand here involves only the function itself and its first derivative.

3. Find the shortest path between two points on a given curved surface. It can be shown that here the integral to be made minimum is

$$S = \int_{x_1}^{x_2} \sqrt{1 + y'^2 + z'^2}\, dx$$

so that here the integrand contains the derivatives of two unknown functions of x.

The method of the Calculus of Variations is based upon the following viewpoint, rather broad but not unnatural. Instead of limiting ourselves to just one definite curve, let us imagine that any curve (or function), including the one we wish to find, is only a special case of a whole infinite family of adjoining curves, all controlled by a certain parameter, the continuous changing of which gradually alters one curve into another. Such a parameter, the existence of which we force, as it were, into the conception of our function, must possess only one property: it must obligingly disappear, whenever, in the continuous changing of curves from one to another, we pass through the form, such as $y = f(x)$, in which we are interested. But it may be in evidence on all other occasions; and, indeed, it can be shown that an infinite variety of curves, such as $y = \phi(x, t)$, can be written down, such that they gradually change one into another, owing to the continuous change of the parameter, t; provided, however, that for some special value of t, say $= t_0$, the function $\phi(x, t_0)$ becomes simply $= f(x)$, the function we have under direct consideration.

Then the differential of the function $\phi(x, t)$ with the specific value, $t = t_0$, substituted in it, is called the *variation* of the function y and is denoted δy. These variations are functions of x, of a perfectly arbitrary nature (since we did not in any way limit ourselves to the manner in which these curves deform into each other), Herein lies the difference between variations and differentials:—the latter (such as dy) are also functions of x, but are not arbitrary, since they are found in a definite way, according to the known rules of calculus. Now, if we want a maximum or a minimum of a definite integral, say S, of a certain expression, involving y or its derivatives, etc., let us again imagine that we deal with a broader conception of y, involving not only x but also the parameter t (the latter, by the way, will be supposed to be such that it merely drops out when y is what we want it to be, in view of our conditions). Then the first derivative of the integral as to the parameter, t, in other words, the variation δS, must be $= 0$ for maximum or minimum of the value of the integral, precisely as $dy/dx = 0$ is the maximum or minimum condition in ordinary calculus.

In other words, when y is what we want it to be, then the integral S does not change for any small increments of the parameter t, whichever way these might take place. Take, for instance, the problem of the shortest distance between two points in a plane or even in space. It makes absolutely no difference what family of curves we assume to deform into each other, as soon as the required minimum is reached (straight line), the curve becomes inert, so to speak, to the changes of the parameter, t. Similarly, in the simple problem of calculus, where the greatest (or least) ordinate is found, y_{max}, we know that in the immediate vicinity of the maximum or minimum value the function refuses to respond to the infinitely small increments of x, and we simply say $dy/dx = 0$. It is not our purpose to give the working methods of the Calculus of Variations, but we will mention the fact that equating to zero of a certain variation of a definite integral (which means maximum or minimum value of said integral) leads to certain differential equations, involving various orders or derivatives of y as to x, as well (generally) as y and x themselves, and constants. Integrating these differential equations, we obtain the required connection between the variables, dependent and independent, a functional relation required, such as $y = f(x)$, clearly establishing the fact that the required curve is a circle or a catenary, etc.

It is well to remember that, in general, the object of differential equations is precisely the research of functional interdependence of variables, from expressions involving their derivatives. From this standpoint the Calculus of Variations supplies means for forming such equations, with a certain object in view—compliance with certain requirements.

2. *Energy.*—In dynamics we are concerned with two forms of energy:—Potential Energy, otherwise known as Latent Energy, or Energy of Position, usually denoted V, and Kinetic Energy, T, otherwise known as Active Energy or Energy of Motion. The sum of these, as is well known, is constant, so that both forms can only transform into each other (dissipation of energy through friction, etc., will not

be considered here); thus a particle, falling from a certain height, in the beginning of motion has no kinetic energy, and at the end, when just reaching the floor, has no potential energy. Similarly a pendulum bob, when in one of its extreme positions, has no kinetic energy; while passing through its neutral position it has no potential energy. It can easily be shown that, in any state of free vibratory motion, the energy, on the whole, is equally distributed into kinetic and potential energies.*

By potential energy more specifically is meant the definite integral, of the virtual work of forces, whose upper limit is determined by some fixed position of reference, and whose lower limit is given by the instantaneous position of the system. In problems involving elastic bodies, this simply means work of deformation, and the energy is often referred to as strain energy, or potential energy of the strain.

Example 1. Tension or Compression.—As is well known from strength of materials:—

$$\frac{F}{a} \div \frac{l - l_1}{l} = E, \text{ that is, } \frac{\text{unit stress}}{\text{unit deflection}} = \text{constant},$$

where F is the force acting on the area a; l and l_1 are the initial length and the stressed length; E is Young's modulus. Hence

$$l - l_1 = \frac{Fl}{aE};$$

and if the load is gradually applied, so that its average value is $\frac{F}{2}$, we have $V = \frac{F^2 l}{2aE}$, which is the required expression of potential energy.

Example 2. Potential Energy of Bending.—Let us consider two sections of the beam, separated by the small length dx. The bending moment, as we know, is $M = \frac{EJ}{\rho}$, where J is the moment of inertia of the cross-section, and ρ is the radius of curvature, equal very nearly to $1 \Big/ \frac{d^2y}{dx^2}$; let us put $\frac{1}{\rho} = \phi$; then the angle α of the two sections will be, of course, such that $\alpha\rho = dx$, in other words, $\alpha = \phi\, dx$.

Let us now bend the beam a little more, so that the angle α will become $\alpha + d\alpha$; this will require the following work:—

$$M d\alpha = EJ\phi\, d\alpha = EJ\, dx\, \phi\, d\phi;$$

in other words, the total work required for securing the desired curvature, starting with a straight bar and reaching a certain value ρ, characterized by a corresponding ϕ, will be—

$$d\,V = EJ\, dx \int_0^l \phi\, d\phi = EJ\, dx \frac{\phi^2}{2} = \frac{EJ}{2}\frac{dx}{\rho^2}.$$

So that the whole potential energy will be—

$$V = \frac{EJ}{2}\int_0^l \frac{dx}{\rho^2} = \frac{EJ}{2}\int_0^l \left(\frac{d^2y}{dx^2}\right)^2 dx.$$

*Ibbetson, "Elasticity," p. 283.

This is sometimes also given in the form—

$$V = \frac{1}{2}\int_0^l \frac{M^2}{EJ}dx.$$

The kinetic energy of a vibrating beam will be found from the following consideration:—The elementary conception, $mv^2/2$, can be extended to a continuous beam if we agree to consider it as an infinity of very thin slices, each possessing a motion of its own. Let the axis x be horizontal and the deflections be denoted in function of the ordinate y. Then the mass of a typical slice will be $dm = \gamma a dx$; and its velocity in its vibratory motion, up and down, will be the time-rate of deflection, that is, $v = \frac{dy}{dt}$.

Therefore the total kinetic energy will be:—

$$T = \frac{1}{2}\int_0^l \gamma\, a \left(\frac{dy}{dt}\right)^2 dx,$$

where γ and a can be taken from under the integral sign only in case of a uniform, continuous beam.

Professor Morley in his book, "Strength of Materials" (section 162), proposes a method whereby the frequency of a vibrating bar can immediatey be found from equating the kinetic energy to the strain energy, which the bar would have in its static deflected position under the same load. The method, although but approximative, is very easy and instructive.

3. *Virtual Work.*—By virtual displacement is understood an infinitely small change of form of a system which *could* take place without being inconsistent with the general characteristics of the system. Such a displacement may or may not be due to the applied forces, but, at any rate, the applied forces may perform a certain amount of work, owing to such an imaginary deflection of the system from its actual position. This deflection can take place in an infinite variety of manners, and all such quantities as may depend on their respective positions will be altered to the extent of certain special differentials, perfectly arbitrary, which we shall denote by δ and call "variations," reserving the notation d for changes actually taking place. By virtual work, then, of a force P, it is proper to call the quantity $P.\delta s.\cos(P,\delta s)$, that is, the product of the force upon the virtual displacement, projected upon the direction of the force.

The virtual work of a resultant, R, of the forces $P_1, P_2, \ldots$ applied to the same point, is the algebraic sum of the virtual works of the components—

$$R.\delta s.\cos(R,\delta s) = \Sigma P.\delta s.\cos(P,\delta s).$$

According to these principles the problems of equilibrium as solved by equating to zero the sum of virtual work of forces; after which we reason as follows:—Since the virtual displacement itself is perfectly arbitrary, it may or may not be $= 0$; therefore to make the whole expression of virtual work equal to zero under all con-

ditions, the coefficient of the displacement must necessarily be $= 0$; and this leads to the desired relations between forces, etc., whence the solution of the problem. In other words, the conception itself of equilibrium means that all forces are quite inert to any small displacement that can be imagined. In a broader sense, and with more special reference to problems of elastic systems, we might say that for equilibrium the variation of the difference $V - W$ must vanish, so that $\delta\ (V - W) = 0$, where V is the potential energy and W the work done in storing it up. The variation sign δ implies that it is absolutely immaterial which way we try to deflect, slightly, such a system—the work done will always be exactly the same as the change of energy, and therefore the system is inert to any such change,—the true definition of equilibrium.

For our immediate purpose we shall, by way of example, take the following problem:—

A beam, AB, is clamped at its right end B and is resting on a continuous, yielding foundation. The beam is loaded with a distributed load, varying, according to the law of triangle, from left to right. The loading is really due to the weight of the beam itself, whose breadth is $= 1$, and whose depth is variable, $h = \xi\, h_0$, where h_0 is the initial value at A, and ξ is a variable coefficient, changing according to the straight line law, $\xi = x/l$; the origin is at A and the beam length is $= l$. Then the variable distributed load will be $q = \xi\, q_0$; and the elastic resistance of the foundation will be $k = \xi k_0$. (This example is a prototype of a more elaborate problem of finding the elastic line of a ship in drydock.) In order to apply the principle of virtual work, let V be the potential energy of the bent beam plus that of the yielding foundation; and let W be the work done by the loading in causing the bending of the beam. Then $\delta\ (V - W) = 0$. In other words, the increment of the function in the brackets, for any possible small deflection from the neutral position of equilibrium, must always be $= 0$.

Now the potential energy will, in our case, consist of two components—that due to the strain energy of the beam itself, and that due to the elasticity of the foundation; the latter will consist of such elemental expressions as $k.\ y.\ dx.\frac{y}{2}$. So that the total potential energy will be—

$$V = \frac{1}{2}\int_0^l EJ\left(\frac{d^2y}{dx^2}\right)^2 dx + \frac{1}{2}\int_0^l ky^2\, dx.$$

The work of the external forces will be, for the deflection of the beam from its original form to that which it will assume under the load,

$$W = \int_0^l qy dx.$$

Remembering that—

$$x = \xi l;\ k = \xi k_0;\ q = \xi q_0;\ \text{also that } J = \frac{h_0^3\, \xi^3}{12},$$

and putting—

$$J = \frac{12 q_0 l^4}{E h_0^3} \text{ and } \gamma = \frac{12 k_0 l^4}{E h_0^3},$$

our variation can be rearranged into—

$$\delta \int_0^l \left[\frac{1}{2} \xi^3 \left(\frac{d^2 y}{d \xi^2} \right)^2 + \frac{1}{2} \gamma \xi y^2 - \lambda \xi y \right] d\xi = 0.$$

Remembering the few remarks made above on the subject of variation, we see that $\delta S = 0$ is the equivalent of the fact that S itself is either maximium or minimum. In other words, that—

$$\int_0^l \left[\frac{1}{2} \xi^3 \left(\frac{d^2 y}{d x^2} \right)^2 + \frac{1}{2} \gamma \xi y^2 - \lambda \xi y \right] d\xi = S$$

must be either maximum or minimum. By actually working out the variation of this integral and equating it to zero, we can obtain a differential equation, the solution of which would give the required answer—the deflection in terms of the abscissa. But a special method will be given in the next chapter, by which the function y can be found without the calculus of variations, by the ordinary calculus rules of finding maxima or minima of functions of several variables. What we have done so far was to establish a certain variational equation, and to conclude therefrom that a certain definite integral must be either maximum or minimum. This is really the starting point of Ritz's method, as will presently be shown, at which time we shall return to this problem.

4. *Hamilton's Principle.*—This very powerful principle of dynamics can be briefly stated as follows: Let T be the kinetic and V the potential energy; let the positions of the system be known at the moments t and t_0. Then for all compatible displacement we have

$$\delta \int_{t_0}^{t} (T - V)\, dt = 0,$$

that is, the variation of the time integral of $(T - V)$ will vanish. For further particulars see Dr. Byerly's "Variations," also Slocum's "Theory and Practice of Mechanics," where an instructive problem will be found worked out in detail—how to find, by Hamilton's principle, the equation of the transverse vibration of a beam; the resulting equation can be written down, almost instantly, from other considerations, but it is important to realize that there actually exists a perfectly general method by which an equation of motion can be derived from the fact that a certain variation of a certain definite integral vanishes. This, by the way, is as far as Hamilton's principle can go—to enable one to form the equation of motion, but not to supply its integrals.

In our problems it will not be necessary to use Hamilton's principle directly, but the principle of virtual work will be applied for finding the variational equations desired. We shall, however, modify the latter to fit the case of elastic vibrations, in the absence of external forces—for every virtual displacement we shall equate the

work of inertia forces to the increase of the potential energy. This will lead to the desired variational equation, which it will be our immediate aim to reduce to the ordinary problem of maxima and minima.

5. *Two Propositions from Calculus;* both are no doubt well familiar to the reader.

(*a*) The minima or maxima values of a function, u, of many independent variables, $x, y, z, \ldots$ is found in rather the same manner as when there is only one such variable, x. We first find the partial derivatives with respect to each independent variable, and equate them to zero.

$$\frac{du}{dx} = 0; \ \frac{du}{dy} = 0; \ \frac{du}{dz} = 0; \text{ etc.},$$

and, further, ascertain whether or not the second derivatives—

$$\frac{d^2u}{dx^2}, \ \frac{d^2u}{dy^2}, \ \frac{d^2u}{dz^2}, \text{ etc.},$$

all have the same sign. If they are all negative, with the values of $x, y, z, \ldots$ found from the above system of first derivatives substituted in them, we have a maximum; otherwise, we have the minimum value of the function u.

(*b*) According to Leibnitz's well-known rule, if we have a definite integral of a function involving an arbitrary parameter, α, in order to find the derivative of the integral with respect to α we simply differentiate under the integral sign. Thus—

$$\frac{d}{d\alpha}\int_a^b f(x,\alpha)\,dx = \int_a^b \frac{df(x,\alpha)}{d\alpha}\,.\,dx.$$

This only applies to the case when the limits are not functions of α, and even then not without certain restrictions, in which, however, we are not here immediately interested.

6. *End Conditions.*—It will be remembered, from the Strength of Materials, that, if x is the abscissa (along the length of the beam) and y the ordinate of the elastic line, in other words, the corresponding deflection, then—

(*a*) dy/dx is the tangent of the very small angle of the elastic line with the original axis of the beam.

(*b*) d^2y/dx^2 is a quantity proportional to the bending moment

$$\left(\text{since } M = EJ/\rho \text{ or } = EJ\frac{d^2y}{dx^2}\right).$$

(*c*) d^3y/dx^3 is proportional to the shear; and

(*d*) d^4y/dx^4 is proportional to the unit load (if distributed). (*c*) and (*d*) are called Schwedler's theorems.

Now in all problems on rod vibrations we shall make constant use of these relations, in adjusting the end conditions to each case, and thereby in determining the required constants of integration, etc. We generally put matters as follows:—At one end (say $x = 0$) we have..... ..... at the other end (where, say, $x = l$) we have ....

For instance, at the clamped end the tangent is $= 0$; at the free end the shear and the moment are both $= 0$. At the supported end the deflection itself is $y = 0$; also the moment $= 0$; but the shear of course is not $= 0$; etc.

IV. RITZ'S METHOD.*

1. Although the delicate mathematical structure underlying Ritz's principle is very elaborate, indeed, the actual working of his method is quite easy, especially in its application to the comparatively simple problems in which we are here interested. In the main, its philosophy is as follows:—

As has been mentioned above, any problem of elastic equilibrium, or motion, can be reduced to some variational equation, in which a variation of some integral is $= 0$. This can either be derived from the principle of virtual work or from Hamilton's principle. Now if a certain variation equals zero, this is precisely the same as to say that some integral must be maximum or minimum; that is what the calculus of variations was invented for. And variations must be used only for the reason that the integrand contains dependent functions, such as y, and their derivatives, so that plain calculus rules of maximum and minimum cannot very well be applied.

Now here is what Ritz proposes. In place of the dependent function (such as y), let us substitute the following tentative expression:—

$$y_n = a_1 \psi_1 + a_2 \psi_2 + \ldots + a_n \psi_n \tag{1}$$

where a_1, a_2, etc., are certain constant coefficients; ψ_1, ψ_2, ... are certain functions, of x only (or of whatever the independent variable happens to be); and n only means the number of terms we wish to assume: for rough results n may be 2 or 3 so that, for instance, the assumed value may be simply—

$$y_2 = a_1 \psi_1 + a_2 \psi_2 ;$$

or, for greater precision, n may be as high as we please. The form of the functions ψ (or ψ (x) as they are sometimes denoted) is rather immaterial, so long as they answer the end conditions in the same manner that y itself would; although some forms may be preferable to others, from the standpoint of labor saving.

As soon as the expression (1) has been substituted into the definite integral, which is generally of some such form as

$$S = \int_0^l f(x, y, y', y'')\, dx \tag{2}$$

the latter, as regards the variables of the problem, becomes merely a function of its limits. The only quantities which we can adjust to the end of having such integral become a maximum or a minimum will be the coefficients a_1, a_2, . . . a_n, regarding

*The following articles have been drawn upon, or consulted, in compiling this chapter:—W. Ritz, *"Oeuvres,"* Paris. 1911. Kryloff, *Sur.... la méthode Ritz*, C. R. 1917, p. 853. H. Lorenz, *Physik. Zeitschr.*, xiv, 1913, p. 71. T. Pöschl, *Physik. Zeitschr.*, xiv, 1913, p. 410. Professor Timoshenko, *"Elasticity"* (Russian), 1916.

which nothing has been said so far; they will temporarily play the part of independent variables in completing our problem, and, according to the ordinary rules of finding maximum and minimum of functions with many variables, we must find derivatives of the given expression with respect to each of these independent variables, and put it $= 0$; so that we shall have (according to the choice of n)—

$$\frac{dS}{da_1} = 0; \frac{dS}{da_2} = 0; - \ldots \frac{dS}{da_n} = 0;$$

from these equations we can find the actual values of the coefficients $a_1, a_2, \ldots a_n$, which solves our problem, because we thus have everything we need to make the tentative solution (1) the required actual solution of the problem. As a matter of fact, working out the variation of the original integral would not have led us to a solution, but only to a differential equation, which we would then have to solve; whereas, by applying Ritz's method, we both avoid the method of variations and at the same time find the solution of the problem itself.

"A mere engineer's method!" exclaimed M. Poincaré, with a touch of something that might have been interpreted as the usual contempt of a man of pure science for a practical man; "except," added he, "that Ritz has supplied an actual rigid proof of the fact that, when n is large, the result can approach the exact solution as close as we please." This proof, by the way, is the main difficulty of the subject, as well as the most brilliant part of Ritz's investigations. If the reader is sufficiently advanced in variations and in the theory of functions, he will greatly enjoy Ritz's original memoirs. We shall limit ourselves to practical problems.

2. *Completion of the Problem Begun under "Virtual Work."*—In our attempt to find the solution of this problem, that is, an expression giving the deflection, y, in terms of the abscissa, x (or ξ, since the variable was changed, for convenience, according to the condition $x = \xi l$), we arrived at the following definite integral:—

$$\int_0^1 \left[\frac{1}{2}\xi^3\left(\frac{d^2y}{dx^2}\right)^2 + \frac{1}{2}\gamma\xi y^2 - \lambda\xi y\right] d\xi = S,$$

of which we were to find the maximum or minimum value—a typical problem of calculus of variations. However, in accordance with Ritz's principle, let us try a tentative substitution:—

$$y_n = a_1\psi_1 + a_2\psi_2 + \ldots a_n\psi_n,$$

where ψ_1, ψ_2, etc., will be certain functions of ξ, the choice of which is more or less arbitrary, as long as they answer the same end conditions as y itself would; the proper form will be suggested presently. Now the coefficients a_1, a_2, etc., constant as they are, will be chosen so that the value of the integral S_n, with y_n substituted in it (for y or its derivatives), will be a maximum or a minimum. Since the integral S_n, with the new value, y_n, substituted in it, is no longer a function of x, but only of the limits, the only variables we have, by which to adjust the value of S_n, are the coefficients a_1, a_2, etc., which, once properly selected, become constants, once and for all, in the solution-to-be-derived, y_n. But they are independent variables, in the process

of finding the conditions under which the integral S_n becomes a maximum or a minimum. Hence all partial derivatives of S_n, with respect to a_1, a_2, etc., must be put $= 0$.

$$\frac{dS_n}{da_1} = 0; \quad \frac{dS_n}{da_2} = 0; \quad \ldots \quad \frac{dS_n}{da_n} = 0.$$

From these equations the coefficients themselves, $a_1, a_2, \ldots a_n$, will then be found, by method of determinants or in any desired manner. The functions ψ_1, ψ_2, etc., can be chosen in a great variety of manners. In the present case we shall take them in form of polynomials:—

$$y_n = (\xi - 1)^2 (a_1 + a_2 \xi + a_3 \xi^2 + \ldots a_n \xi^{n-1})$$

or, limiting ourselves to $n = 3$, this will be—

$$y_3 = (\xi - 1)^2 (a_1 + a_2 \xi + a_3 \xi^2)$$

or, in a different form,

$$y_3 = a_1 (\xi - 1)^2 + a_2 (\xi - 1)^2 \xi + a_3 (\xi - 1)^2 \xi^2.$$

Indeed, it is easy enough to see that on the right end of the beam, where $\xi = 1$, this expression satisfies the condition of both y and $dy/d\xi$ being $= 0$.

On the left end the condition $EJ \frac{d^2y}{dx^2} = 0$ (the bending moment equals zero), is automatically fulfilled by the fact that the moment of inertia, J, itself vanishes at $\xi = 0$, owing to the triangular nature of the beam profile.

Substituting this value of y_3 into the integral S, and differentiating with respect to a_1, a_2 and a_3, we have the following system of linear equations:—

$$a_1 \left(1 + \frac{\gamma}{30}\right) + a_2 \left(\frac{2}{5} + \frac{\gamma}{105}\right) + a_3 \left(\frac{1}{5} + \frac{\gamma}{280}\right) = \frac{\lambda}{12}$$

$$a_1 \left(\frac{2}{5} + \frac{\gamma}{105}\right) + a_2 \left(\frac{2}{5} + \frac{\gamma}{280}\right) + a_3 \left(\frac{2}{7} + \frac{\gamma}{630}\right) = \frac{\lambda}{30}$$

$$a_1 \left(\frac{1}{5} + \frac{\gamma}{280}\right) + a_2 \left(\frac{2}{7} + \frac{\gamma}{630}\right) + a_3 \left(\frac{9}{35} + \frac{\gamma}{1260}\right) = \frac{\lambda}{60}$$

Assuming $\gamma = 10$ we have the following expressions of the constants a_1, a_2, a_3 in terms of λ:—

$$a_1 = .05869\,\lambda; \quad a_2 = .0013\,\lambda; \quad a_2 = -.002164\,\lambda;$$

and if γ is taken $= 100$, then

$$a_1 = .01251\,\lambda; \quad a_2 = .0212\,\lambda; \quad a_3 = .00079\,\lambda.$$

Had we taken $n = 2$, that is, had we limited ourselves to two terms in the expression of y, $y_2 = a_1 + a_2 \xi$, the results would have been as follows:—

If $\gamma = 10$, $\quad a_1 = .0589\,\lambda$; $a_2 = .00946\,\lambda$.

If $\gamma = 100$, $\quad a_1 = .0124\,\lambda$; $a_2 = .0218\,\lambda$.

Had this elastic line been established according to exact methods, the discrepancies would have been proven not to exceed 1 to 2 per cent, for both the deflection

and the maximum bending moment, at least for greater values of γ; this will indicate that the precision of Ritz's method is sufficient for practical applications even if n is not great. If the moment of inertia at the left end of the beam is not $= 0$, a different expression for ψ will have to be chosen, so that the end conditions (the moment and the shear both vanish):—

$$\left(\frac{d^2\psi}{d\xi^2}\right)_{\xi=0} = 0; \qquad \left(\frac{d^3\psi}{d\xi^3}\right)_{\xi=0} = 0,$$

are satisfied.

Here the form of the functions ψ may be taken as follows:—

$$y_3 = a_1\left(1 - \frac{4}{3}\xi + \frac{1}{3}\xi^4\right) + a_2(\xi - 4\xi^4 + 3\xi^5) + a_3(\xi^4 - 2\xi^5 + \xi^6).$$

This type may be applied to all cases where the beam depth is varying according to a law of straight line or of parabola, that is when

$$h = h_1 + (h_0 - h_1)\,\xi,$$

or when

$$h = h_1 + (h_0 - h_1)\,\xi^2.$$

Having thus found the necessary coefficients, a_1, a_2, etc., we can change the independent variable back to x, and then write down the first answer giving the deflection, y, in function of the abscissa, x.

3. *Vibrations of Beams with Variable Cross-section.*—The fundamental variational equation of motion can be formed as follows:—

Let V be the potential energy.

l the length of the beam,

y the deflection on abscissa x.

γ the weight of 1 cubic foot of material.

F the area of cross-section.

E the modulus of elasticity.

J the moment of inertia of the cross-section.

Then, expressing the fact that, for any virtual displacement, the work of the inertia forces $\left(\Sigma\left(-m\frac{d^2y}{dt^2}\right)\right)$ is always equal to the corresponding increase of the potential energy, we can write—

$$\delta V + \int_0^l \delta y \,.\, \frac{\gamma F}{g} \,.\, \frac{d^2y}{dt^2} \,.\, dx = 0.$$

Remembering the expression of potential energy of bending in terms of y, assuming also that y changes according to some such law as—

$$y = \text{const.} \times \cos pt$$

(in other words, introducing the frequency-constant, p) we can reduce this expression to

$$\delta \int_0^l \left[\frac{EJ}{2}\left(\frac{d^2y}{dx^2}\right)^2 - \gamma\frac{Fp^2}{2g}y^2\right] dx = 0.$$

As has been explained above, the fact that a variation of a definite integral is $= 0$ means that the integral itself must be either maximum or minimum. Therefore our problem is reduced to finding maximum or minimum of the integral—

$$\int_0^l \left[\frac{EJ}{2}\left(\frac{d^2y}{dx^2}\right)^2 - \gamma\frac{Fp^2}{2g}y^2\right]dx = S \text{ (say)},$$

observing, of course, the end conditions.

We shall avoid the methods of the calculus of variations, also secure a direct solution, by again applying Ritz's method, that is, by assuming, tentatively—

$$y_n = a_1\psi_1 + a_2\psi_2 + \ldots a_n\psi_n,$$

where $\psi_1, \psi_2, \ldots \psi_n$, are functions of x, and the coefficients, $a_1, a_2, \ldots . a_n$, are, in broader sense, special coordinates; by assuming a certain n, we transform the system into one with, as it were, n degrees of freedom. These coefficients, $a_1, a_2, \ldots . a_n$, are found from a system of equations—

$$\frac{dS_n}{da_1} = 0; \ldots . \quad \frac{dS_n}{da_n} = 0;$$

each of which is a partial derivative of the integral with the assumed value y_n substituted in it, made equal to zero, in our attempt to find such values of a_1, etc., that the integral S will be a maximum or minimum. Here we also start with the assumption of a certain form for y, the deflection, as above, but our real object is to find the frequency constants of various modes of vibrations, as will be made clear through the following examples.

As an example let us take a clamped wedge, whose width is constant and whose depth varies according to the law of an equilateral triangle, the depth initially being $= 0$, and increasing to $2b$ at the clamped end. Let us take the origin at the left, free end of the beam, whose length is l, the axis, y, of deflection, being, of course, directed downward; let us introduce the substitution $x = \xi l$, so that the integral becomes, upon substitution of the variable values of the area and the moment of inertia—

$$S_n = \int_0^l \left[\frac{Eg}{\gamma}\cdot\frac{b^2}{3l^4}\cdot\xi^3\left(\frac{d^2y_n}{d\xi^2}\right)^2 - p^2\xi y_n^2\right]d\xi.$$

As regards the end conditions, the following remarks can be made. At the left end both the bending moment and the shear vanish in view of the pointed nature of the beam. At the right end the deflection and the angle of the elastic line with the x axis are both $= 0$; that is—

$$(y)_{x=l} = 0; \left(\frac{dy}{dx}\right)_{x=l} = \frac{1}{l}\left(\frac{dy}{d\xi}\right)_{\xi=1} = 0.$$

The tentative expression for y_n may be taken of the same form as above:—

$$y = (\xi - 1)^2\,(a_1 + a_2\xi + a_3\xi^2 + \ldots).$$

Indeed, when $\xi = 1$, both y and its derivative vanish.

The first approximation may be obtained by limiting ourselves to the first term of the expression y^n, that is, by making $n = 1$. Then

$$y_1 = a_1 (\xi - 1)^2 \text{ and } \frac{d^2 y}{d\xi^2} = 2 a_1.$$

Substituting these values into the integral S_n we have, on integration—

$$S = \frac{Egb^2}{\gamma 3 l^4} a_1^2 - \frac{p^2}{30} a_1^2.$$

Here there is only one derivative to be taken for establishing that value of a_1 which will make the integral maximum or minimum.

From $\frac{dS_1}{d a_1} = 0$ we find—

$$p_1 = \frac{b}{l^2}\sqrt{\frac{10 Eg}{\gamma}} = 5.48 \frac{b}{l^2}\sqrt{\frac{Eg}{3\gamma}}.$$

This result differs only by about 3 per cent from the exact answer, worked out by other methods, more difficult and not applicable to more complicated problems of this nature, where Ritz's method is of especially great value.

By way of second approximation let us make $n = 2$, that is, assume

$$y_2 = (\xi - 1)^2 (a_1 + a_2 \xi),$$

whence—

$$\frac{d^2 y_2}{a\,\xi^2} = 2 (a_1 - 2 a_2 + 3 a_2 \xi).$$

Substituting into the integral we have, carrying out the integration—

$$S_2 = \frac{Eg}{\gamma} \cdot \frac{b^2}{3 l^4}\left[(a_1 - 2 a_2)^2 + \frac{24}{5} a_2 (a_1 - 2 a_2) + 6 a_2^2\right] - p^2 \left(\frac{a_1^2}{30} + \frac{2 a_1 a_2}{105} + \frac{a_2^2}{280}\right).$$

Equating to zero the partial derivative of this expression as to a_1 and a_2, that is, $\frac{dS_2}{d a_1} = 0$ and $\frac{dS_2}{d a_2} = 0$, we have—

$$\left(\frac{Eg}{\gamma} \cdot \frac{b^2}{3 l^4} - \frac{p^2}{30}\right) a_1 + \left(\frac{2}{5}\frac{Eg}{\gamma} \cdot \frac{b^2}{3 l^4} - \frac{p^2}{105}\right) a_2 = 0;$$

$$\left(\frac{2}{5}\frac{Eg}{\gamma} \cdot \frac{b^2}{3 l^4} - \frac{p^2}{105}\right) a_1 + \left(\frac{2}{5}\frac{Eg}{\gamma} \cdot \frac{b^2}{3 l^2} - \frac{p^2}{280}\right) a_2 = 0.$$

Such a system of equations can have the values of a_1 and a_2 different from zero only upon the condition that the determinant of the coefficient is $= 0$, that is, if—

$$\left(\frac{Eg}{\gamma}\frac{b^2}{3 l^4} - \frac{p^2}{30}\right)\left(\frac{2}{5}\frac{Eg}{\gamma} \cdot \frac{b^2}{3 l^4} - \frac{p^2}{280}\right) - \left(\frac{2}{5}\frac{Eg}{\gamma} \cdot \frac{b^2}{3 l^4} - \frac{p^2}{105}\right)^2 = 0,$$

whence we have two values of p^2. The smaller value of p, corresponding to the fundamental tone, is

$$p = 5.319 \frac{b}{l^2}\sqrt{\frac{Eg}{3\gamma}},$$

which is still nearer the exact solution:—

$$p = 5{\cdot}315 \frac{b}{l^2} \sqrt{\frac{Eg}{3\gamma}}.$$

The other root would give the first overtone, but with less accuracy. If greater precision is desired for harmonics, it is necessary to take larger values for n, whereby more unknowns to find and a higher order of the corresponding determinant.

4. *Hull as a Free-free Bar.*—Applying Ritz's method to the problem of finding the fundamental tone of free vibrations of vessels let us consider the hull as a free-free bar of variable cross-section, irregularly loaded.

Let both the curve of moments of inertia and the curve of loads be parabolic curves, symmetrical with the middle of the ship, which will be our origin; let the length be $= 2l$. The moments of inertia will be given by—

$$J = J_0 (1 - bx^2).$$

Also the load curve will be

$$F = F_0 (1 - cx^2),$$

where b and c are suitable constants.

The tentative substitution will be of the same form:—

$$y_2 = a_1 \psi_i + a_2 \psi_2,$$

limiting ourselves to but two terms; the form of the functions ψ_i will be taken as follows:—

$$\psi_i = \frac{\cosh k_i \cos \frac{k_i x}{l} + \cos k_i \cosh \frac{k_i x}{l}}{\sqrt{\cos^2 k_i + \cosh^2 k_i}}$$

where the transcendental equation for k_i will be

$$\tan k + \tanh k = 0$$

(thus ψ_i will be recognized as an even normal function for the case of a free-free prismatic bar.)

These functions, ψ_i, will be easily seen to satisfy the end conditions—

$$\left(\psi_i\right)''_{x=l} = 0 \text{ and } \left(\psi_i\right)'''_{x=l} = 0.$$

In order to simplify writing let us assume—

$$\lambda = \frac{F_0}{J_0} \cdot \frac{\gamma}{g} \cdot \frac{p^2}{E};$$

also

$$\int_{-1}^{+1} (1 - bx^2) \psi_i'' \psi_j'' \, dx = \alpha_{ij}; \qquad \int_{-1}^{+1} (1 - cx^2) \psi_i \psi_j \, dx = \beta_{ij};$$

so that the partial derivatives—

$$\frac{dS_n}{d a_1} = 0; \quad \frac{dS_n}{d a_2} = 0; \text{ etc.,}$$

can be written simply as—

$$\sum_{i=1}^{i=2} a_i(\alpha_{ij} - \lambda\beta_{ij}) = 0$$

The first two roots of the transcendental equation—

$$\tan k + \tanh k = 0$$

are—

$$k_1 = 0 \text{ and } k_2 = 2.365.$$

So that—

$$\psi_1 = \text{const.}\ ;\ \psi_2'' = \frac{k_2^2}{l^2} \cdot \frac{\cos k_2 \cosh \frac{k_2 x}{l} - \cosh k_2 \cos \frac{k_2 x}{l}}{\sqrt{\cos^2 k_2 + \cosh^2 k_2}}$$

To the first term of the series will thus correspond a bodily displacement of the bar (no bending); the second term will mean a certain elastic curve corresponding to the fundamental tone of a free-free bar.

If $\psi_1 = 1/\sqrt{2}$, the values of α and β will be as follows: $\alpha_{11} = 0$; $\alpha_{12} = 0$;

$$\alpha_{22} = \int_{-l}^{+l} (1 - bx^2)(\psi_2'')^2 dx = \frac{31.28}{l^3}(1 - .087\, bl^2);$$

$$\beta_{11} = l\,(1 - .333\, cl^2);\ \beta_{12} = .297\, cl^3;\ \beta_{22} = l(1 - .481\, cl^2);$$

and our maximum-minimum conditions will be:—

$$a_1(\alpha_{11} - \lambda\beta_{11}) + a_2(\alpha_{21} - \lambda\beta_{21}) = 0;$$

$$a_1(\alpha_{12} - \lambda\beta_{12}) + a_2(\alpha_{22} - \lambda\beta_{22}) = 0.$$

In order that a_1 and a_2 may not be identically $= 0$, the determinant must vanish; hence, since $\alpha_{11} = \alpha_{12} = 0$,

$$\lambda^2\left(1 - \frac{\beta_{12}^2}{\beta_{11}\beta_{22}}\right) - \lambda\frac{\alpha_{22}}{\beta_{22}} = 0.$$

The first root ($\lambda = 0$) means a non-vibratory displacement; the second root,

$$\lambda = \frac{\alpha_{22}}{\beta_{22}} \cdot \frac{1}{1 - \frac{\beta_{12}^2}{\beta_{11}\beta_{22}}}$$

will determine the frequency-constant of the fundamental tone through—

$$p = \sqrt{\frac{\lambda J_0 g E}{F_0 \gamma}}.$$

In Professor Timoshenko's treatise, from which this problem has been adapted, the following practical illustration is given (in round figures):—

Let the characteristics of a 5,000-ton vessel be:—

$$2l = 328 \text{ ft.};\ J_0 = 2{,}316 \text{ ft.}^4;\ F_0\gamma = 1{,}437g\,\frac{\text{lbs.}}{\text{ft.}};\ b = c = 2.79 \times 10^{-5};$$

The displacement will then be—

$$D = \frac{2 \times 1437 + 32.16}{2240} \int_0^l (1 - .0000279\, x^2)\, dx = \text{about } 5{,}100 \text{ tons.}$$

We first calculate the coefficients:—

$$\alpha_{22} = 6.46 \times 10^{-6};\ \beta_{11} = 123;\ \beta_{12} = 36.6;\ \beta_{22} = 104.7$$

Then

$$\lambda = 6.97 \times 10^{-8}.$$

And, if

$$E = 4.32 \times 10^9 \frac{\text{lbs.}}{\text{ft.}^2},$$

the frequency-constant will be $p = 23.5$, so that the corresponding number of revolutions will be (about)—

$$N = \frac{60p}{2\pi} = 224 \text{ R. P. M.}$$

This example is given, of course, only for the purpose of illustrating the working of the method; it involves integration by parts of the easiest kind possible.

In actual practice neither the load curve nor the curve of moments of inertia is parabolic or symmetrical. It becomes necessary, therefore, to resort to graphical methods, perfectly evident, in working out the expressions of α's and β's. It will be remembered, of course, that in integrating the product of two curves it is necessary to plot an additional curve, of which every ordinate is the product of the corresponding ordinates of the two curves; then ordinary methods can be applied, planimeter, Simpson's rule, etc.

After the α's and β's have been found, the problem is completed exactly as above.

The values of the hyperbolic sine and cosine will be found in Smithsonian Tables or in Mellor's "Higher Mathematics," where also an easy exposition is given of the elements of the general theory of hyperbolic functions and their applications.

5. *Remarks.*—The importance of a practical method whereby to find an approximate value of the fundamental frequency cannot be overestimated; anyone interested in designing a ship, in its construction or equipment, would naturally give almost anything to know, beforehand, the rotative speeds, from which to keep away, in specifying or installing all machinery.

In reviewing various causes to which forced vibrations may be due one is somewhat surprised to see that the effect of skin friction has been rather overlooked; yet it is not unlikely that this may start longitudinal vibrations, in much the same manner as a violin bow in a steel rod clamped in the middle.

Another point which is mostly overlooked is the question of balance. Dr. Schlick and others explain vibrations by everything under the sun—the transverse couple, the unbalanced forces or couples of the reciprocating mechanism; the slight difference of pitch of the propeller blades; the wrong number of blades; too little

free space between propeller tips and the hull; in fact, everything but plain static and dynamic unbalance. The latter may be considerable, and it is not clear why one should look for any other causes before this, most immediate, source of trouble, so easy to detect and to remove, has been looked into.

DISCUSSION.

The President:—This paper, No. 8, entitled "On Vibrations of Beams of Variable Cross-Section," is now open for discussion. Is there any member who desires to say anything in connection with this subject?

Commander William McEntee, C. C., U. S. N., *Member:*—As I received a copy of this paper only two days ago, I have not been able to give it the careful study which it merits. From experience I have had in measuring vibrations on naval vessels I can heartily endorse the statement made by the author on page 113 that the hull of a ship vibrates as a beam and not as a string.

In connection with the general subject, I would like to inquire of the author whether he has read the valuable papers on the subject of ship vibrations by Dr. Gümbel published in the Jahrbuch der Schiffbautechnischen Gesellschaft in 1902 and published in the Transactions of the Institution of Naval Architects in 1912. In those papers Dr. Gümbel gave two very valuable rules connecting the frequency of vibrations and the lengths of similar ships. These are as follows:—(1) The frequency of the natural periods of vibration for similar ships are inversely proportional to the linear dimensions. (2) The product of the frequency and the length of the ship are constant for similar vessels. Dr. Gümbel states that, in the measurements made by Schlick on the German cruiser Vineta, the number of first order vertical vibrations per minute multiplied by the length of the ship in feet was 45,300.

In measurements made on the battleships Kansas and Arizona, I found on the Kansas the first period vertical vibration had a frequency of 101. As the ship's length between perpendiculars is 450 feet, the product is 45,450. On the Arizona, the length of which is 600 feet between perpendiculars, the first-period vertical vibration had a frequency of 76, the product being 45,600. This agreement, with Schlick's results on the Vineta, is remarkably close.

For second-period vertical vibrations I found on the Kansas, and on her sister ship, the Minnesota, the frequency to be 220. The Minnesota was fitted with a four-bladed propeller. The second-order vertical hull vibrations occurred when the engines were making 55 revolutions per minute, whereas on the Kansas, which was fitted with three-bladed propellers, the same vibrations appeared when the engines were making 73 revolutions per minute, thus indicating clearly that the vibrations were due to the propeller blades.

These vibrations were not due to the unbalanced forces of the engines themselves, for when the Minnesota's engines were run with propeller uncoupled, no vibrations appeared either at 55 or at 73 revolutions. It is interesting to note that the ratio between the first and the second period vibrations on the Minnesota was 2.2. This may be compared with the figures given by the author for the vibrations of a free bar of uniform cross-section.

We disconnected the propellers in the Minnesota to run the engines uncoupled, and found

no vibration due to these two speeds, so that the vibration could not be due to the reciprocating forces of the engine.

The measurement of vibrations on the Minnesota was brought about by the fact that considerable trouble had been experienced with shaft breakages on battleships of this class, which it was thought were fundamentally due to hull vibrations and lack of rigidity in the engine and shaft-bearing foundations.

I was a member of a board which conducted tests both on the Minnesota and the Kansas to ascertain, if possible, the causes for the shaft breakages. The results were very interesting and will no doubt be of interest to the Society in connection with the general subject of ship vibration. On both ships at engine speeds of 80 to 81 revolutions per minute there were found to be marked vertical hull vibrations with a frequency of 320. As the engines were triple-expansion engines with two low-pressure cylinders, that is, four pistons and cranks, the vibrations could possibly have been due to the unbalanced forces of the engines; but as the period at which the trouble was experienced did not agree with any natural period which could be expected from the hull structure, an investigation was made of the possibility of torsional vibrations in the shaft.

The results were very interesting. At the critical speed—that is, about 80 or 81 revolutions—there was found, by means of a torsion meter which would record the torsional stress in the shaft during a complete revolution, that, when the shaft was transmitting a torque corresponding to a mean maximum sheering stress of 3,000 pounds per square inch, the shaft was in torsional vibration so that the real stress in it varied from 3,000 pounds negative to 12,000 pounds positive. In other words, there was a complete reversal of stress, and the maximum positive stress was four times that which could be expected from the mean load transmitted. This reversal stress occurred 320 times a minute and readily accounted for the breaking of the shafts.

This torsional stress, when reacting through the crank pins on the connecting rod and pistons, resolved itself into bending stresses on the crank shaft. This, transmitted through the engine frame and foundations, resulted in the forced hull vibrations which were, of course, caused by the shaft. Instead of the shaft breakages being due to hull vibrations they were due to torsional vibrations of the shaft, and the hull vibrations were a symptom, not the cause of the disease.

This torsional stress on the shaft, as I say, reacted through the crank pins and connecting rods and resolved itself into fore-and-aft bending moments on the crank shaft.

This, in turn, was transmitted to the hull and caused the hull to vibrate at the same period as the torsional vibration of the shaft.

The President:—Is there anyone else who has anything to add to this discussion?

Mr. E. H. Rigg, *Member:*—Mr. Chairman and gentlemen, the Society is to be congratulated on Mr. Akimoff's paper, because it is one which treats of an extremely difficult subject. Most previous investigations have been confined to the balancing of the engines, that being a field in which a great deal of work has been done. The Transactions of this Society and of kindred societies contain much interesting literature on the subject of balancing engines, and the art is thoroughly well understood at the present time.

Commander McEntee referred to some interesting investigations; perhaps, as a matter of record, I may say that the results of those or similar investigations were published in 1912,

in a paper contributed to the Institution of Naval Architects by Dr. Gümbel, who there gives further references to similar work in French and German publications.

It is of great interest to hear from Commander McEntee how this method has been verified by experience in our Navy.

The following list of references may prove useful.

From our own Transactions:—"Balancing of Marine Engines"; 1901, Rear Admirals D. W. Taylor and G. W. Melville, U. S. N. "Vibration of Steamships"; 1902, Rear Admiral G. W. Melville, U. S. N. "Period of Vibration of Steam Vessels"; 1915, W. Gatewood.

From the Institution of Naval Architects, London:—"Torsional Vibration of Shafts"; 1902, Dr. L. Gümbel. "Our Present Knowledge of the Vibration Phenomena of Steamers"; 1911, Dr. O. Schlick. "Torsional Vibrations of Elastic Shafts of Any Cross-section and Mass Distribution, and Their Application to the Vibration of Ships"; 1912, Dr. L. Gümbel, "Some Experiments on the Influence of Running Balance of Propellers on the Vibration of Ships"; 1917, J. J. King-Salter, R. C. N. C.

Captain W. Hovgaard, *Member* (Communicated):—Mr. Akimoff's paper is of great value to the profession, as it affords an excellent introduction to the problem of vibrations, giving a comprehensive and yet brief view of the present status of the science. His exposition of Ritz's method is of great interest in that it enables the naval architect to deal in a relatively simple manner with the most complex problems that are likely to occur in the study of deflections and vibrations of ships.

In the discussion of the principle of virtual work, Mr. Akimoff refers to the problem of finding the elastic line for a ship in dock. This is a subject to which I have given considerable study, and my general impression is that when a ship is well supported it does not, except for the overhanging parts at the ends, take any appreciable deflection as a girder. It behaves more as a limber body with rather insignificant deflections determined chiefly by the local distribution of the weights in the ship and of the keel blocks. Thus points of increased compression of the blocks are likely to be found at each of the main transverse bulkheads. This remark applies in particular to large vessels and where the total area and distribution of the blocks are in accordance with good practice. The deflection of the overhanging ends may be considerable, but will rarely cause excessive general strains in the structure. The deflection of such parts can, of course, be determined graphically by the theory of bending.

It would be of interest to know more definitely what Mr. Akimoff means by "plain static and dynamic unbalance" to which, on the last page of the paper, he ascribes vibrations. I confess I belong to those who believe that vibrations are due chiefly to the action of the engines and the propellers.

Commander J. J. Manning, U. S. N. (Communicated):—On a ship at sea, steaming at normal speed, I have noticed in some cases very little vibration up to a certain point. At this point, termed "critical speed," which I have noticed, while standing watch on the bridge (located one-half the distance between the center, or amidship section, and the bow), the vibration is excessive, having an amplitude, I should judge, anywhere from one-half inch to one inch.

One particular instance I recall. While officer on the bridge at sea, on one of our battleships in fleet formation, we suddenly lost one blade of our starboard propeller. We were

steaming along at a speed of about 15 knots. The minute the blade dropped off a tremendous vibration was set up, and, judging from the difficulty experienced in standing perfectly rigid on the bridge, the amplitude of the vibration was at least one inch. I also found, from practical experience, that the vibration is always in the vertical plane and never in the horizontal plane, no matter what the cause of this vibration may be.

I have noticed, in some of our cruisers, that the reciprocating generators in action will cause considerable vibration while the ship is dead in water. It seems that at certain times the vibration of the machine itself would get into synchronism with the vibration of the ship and accelerate it to such an extent that it would be felt in the after end of the ship and in the forward end, but would not be very noticeable amidships. This is the case in all ships whether steaming or at anchor, that is to say, the vibration is excessive at the extreme ends, but very moderate amidships.

I can personally recall hundreds of instances where the above has occurred on board ship during my career in the service.

Prof. S. E. Slocum (Communicated) :—Mr. Akimoff's article on "Vibrations of Beams of Variable Cross-Section" affords an interesting summary of the methods applicable to problems of this type. There is one general method, however, which does not seem to be mentioned, but which is of such importance that it should certainly be included in the summary, namely, the application of Fourier's integral or Fourier's series.

The method generally followed in mathematical physics is to state the physical conditions underlying a given problem in the form of a partial differential equation. Such a differential equation is of course simply a symbolic statement of the problem and can usually be written down without difficulty. Its importance lies in the fact that when once formulated it presents the conditions governing the problem in a functional form and therefore involves implicitly not only the known facts from which it was obtained but also the unknown circumstances attending the phenomena.

It is usually possible to find by trial, or otherwise, a set of particular solutions satisfying the given differential equation. From these there may be selected a set which also satisfy the given boundary conditions of the problem. In the case of a vibrating rod, these boundary conditions would be the end conditions of the rod as determined by its restraints, etc.

Now it is evidently possible to form a series of terms from these particular solutions such that this series will satisfy the original differential equation and also the boundary conditions of the problem. Also, as in the case of Ritz's method, the more terms this series includes the more nearly will the solution it represents approach the general solution of the problem. An infinite series of such terms, provided it is convergent, can thus be made to define a function which is the required general solution of the original differential equation. Now Fourier's integral is an expedient for determining the function defined by such an infinite series of terms, and therefore affords a method for determining the function representing the general solution of the given partial differential equation. The use of Fourier's integral, which is a limiting form of Fourier's series, thus provides a powerful general method which has a wide application to problems of the type here considered.

Lieut. W. L. Kraemer, U. S. N. (Communicated) :—In reading over an advance copy of the paper on "Vibrations of Beams of Variable Cross-Sections," by Mr. N. W. Akimoff, a few points that might be relative to the discussion are mentioned, that is, that with a ship

traveling at speed the depth of the water in which the vessel is running has a distinct bearing on its trim. A ship running at speed in very shallow water will drag down at the stern more than when running at the same speed in a greater depth.

Also, in most previous cases of observation of vibration, the period of vibration has been observed while the ship was made fast to a dock with the machinery running, as in the case of a dock trial.

Would not the method of securing the ship to the dock, and also the position of the helm, have a distinct bearing on the stresses existing in the vessel, and therefore a bearing on the period of vibration?

These two observations are submitted merely with a view that, in the discussion of this paper, they may have some bearing on the subject.

Rear Admiral C. W. Dyson, U. S. Navy (Communicated) :—I have read through the paper on "Vibration of Beams of Variable Cross-Sections," prepared by Mr. Akimoff, but am sorry to say that my time is so fully occupied that I have not been able to make such a study of the paper as its character justifies.

I can say, however, that for some time back we have been balancing turbines, and in some cases propellers, for our vessels, following in general the method pursued by Mr. Akimoff and at times employing Mr. Akimoff to conduct the balancing test. In all vessels where this balancing has been accomplished and the vessels have been tried in service, the lack of vibration experienced has been very noticeable as compared with previous vessels.

Mr. F. Hymans (Communicated) :—In the science of dynamics there is no more fascinating subject, nor one of greater importance for the engineer, than that of the motion of elastic systems. According thereto, an elastic system moves as if it were perfectly rigid, superposed by a motion of its constituent parts relative to each other.

Take for example a wheel rolling on a rail. Each of its material points tends to describe cycloidal paths, with velocities, which within each revolution continually change in magnitude as well as in direction. These changes are only then possible when each material point is subject to certain forces exerted upon it by the surrounding matter, and we recognize that, while the body rolls, the stresses in each of its material points must vary to correspond to the motion impressed upon it.

But a stress is always accompanied by a deformation, and hence, while a wheel rolls, there occurs a continual change of figure of the wheel as a whole, which we call a vibration.

How many who have looked upon a rolling wheel have been alive to the fact that there is internally a continuous process of readjustment going on, in the endeavor of the wheel actually to roll?

And so it is with most machinery in motion. Superficially the appearance is that of equilibrium, yet in reality equilibrium is seldom the fact; and upon closer investigation we see that ever-changing conditions occur which set up internal stresses and become manifest in vibrations if these changes occur rapidly enough.

In the majority of cases, as in the example of the rolling wheel, the vibrations in machines are set up by inertia forces; that is to say, they are due to certain motions impressed on its material points. If so, the forces corresponding to the impressed motions pass within given intervals through one and the same cycle, and are therefore periodic. Now we know that if the frequency of these forces is the same as the frequency of the free vibration of the system, the vibrations set up by them will be extremely severe.

This is what we call resonance, and the explanation of the phenomenon is as follows:—

Let a material point vibrate with the constant frequency f, but with amplitudes which also depend on the time, and let its velocity v be expressed by—

$$v = f(t) \sin 2 \pi f t.$$

We are here not concerned in the precise form of the function $f(t)$, but make the stipulation that it is positive for any value of the time t.

The frequency f is of course the frequency of the free vibration, for in the absence of external forces nothing must change, except that the function $f(t)$ becomes a constant. Let, further, the above vibration be excited by an external force of the same frequency f, and expressed by

$$P = A \sin 2 \pi f t.$$

The rate of work done by the force P on the material point is Pv, for which we obtain—

$$Pv = f(t) \sin^2 2 \pi f t$$

an expression of which the smallest value will be zero, but which never becomes negative. But if the rate of work done on the material point never becomes negative, the energy $\int_0^t Pv dt$ absorbed by it will indefinitely increase with time, which is equivalent to saying that the vibrations will occur with ever-increasing violence.

Thus we see that feeble periodic forces in resonance with the free vibration will with time—and only then—exert effects altogether out of proportion with their magnitude.

And it follows that a machine may be run at a speed higher than the one which brings about resonance, provided that it is passed through the critical speed fast enough. A celebrated example of this is the starting up of a De Laval steam turbine.

In the foregoing, damping of the vibrations has been left out of consideration. With damping the statement should be modified to say that at resonance the energy absorbed by a vibrating system increases with time until a point is reached where the work done by the external force on the system is equal to the energy dissipated by it.

Therefrom we see that vibrations are maintained by the expenditure of a given amount of power which, in case of ships, must be supplied by the propelling machinery.

From whatever point of view we look at it, one of the most important questions in naval engineering is the predetermination of the periods of free vibration of the hull.

As an example, it may be cited that in the two-cycle Diesel engine ship, the Monte Penedo, designed initially for an engine speed of about 154 revolutions per minute, the vibrations at that speed were such that the speed had to be reduced to about 135 revolutions per minute.

We are therefore greatly indebted to Mr. Akimoff for his paper, wherein he shows that the necessary mathematical apparatus to deal with such problems already exists.

With particular reference to Timoshenko's application of the Ritz principle to the calculation of the periods of free vibration of a ship, it should be pointed out that the fundamental variational equation and the subsequent operations are true if the following conditions are verified.

1. That the axis of the bar, when without stress, is straight.

2. That a cross-section of the bar is not sensibly altered in its internal arrangement in the bending.

3. That the bending consists of a rotation of each cross-section around an axis passing through its center of gravity.

4. That the kinetic energy due to the rotation of the material points of each cross-section around the above axis may be neglected.

5. That the potential energy of shear is negligible.

6. That the deflections are very small.

In the application to vibration of ships, the following of the above conditions are surely not verified.

1. The axis, being the line joining the centers of gravity of the cross-sections, is not straight.

2. In a beam, consisting of cross-sections as we have in a ship, shear must play an important part, neither can it be assumed that the cross-sections remain plane without sensible alteration of their figure.

The above statements are made for the single purpose that we should not expect too much of an agreement between calculation and actual results. But even so, it surely is a remarkable achievement to be able to determine the periods of free vibration of as complicated a structure as a ship if only with a fair degree of accuracy.

As to the propelling machinery for ship of average size, the contending systems to-day are the steam turbine and the Diesel engine, the latter in the writer's opinion a sure winner in the near future.

Thanks to Mr. Akimoff's paper and enterprise, turbine rotors are to-day balanced statically as well as dynamically. While therefore initially we start off with ideal conditions, it nevertheless remains true that wear of the turbine blades takes place and so gradually destroys the perfect balance. With Diesel engines, on the other hand, periodic impulses to the ship's hull may be minimized with good design, but cannot altogether be avoided, no matter what we do.

In an unbalanced turbine rotor the horizontal and vertical components of the forces set up by its rotation are equal in magnitude, and each of them is capable to excite vibrations. With this type of propulsion, therefore, it is necessary to ascertain the periods of the free transverse vibrations of the hull in the horizontal as well as in the vertical plane. With Diesel engines the horizontal component of the inertia forces is small and can be taken care of, and we are therefore mainly interested in the period of the vibrations in the vertical plane.

The President:—I think the thanks of the Society are due to Mr. Akimoff for his paper, and if he will accept the same without a formal motion, we will be glad to tender our thanks to him.

Rear Admiral Francis T. Bowles, *Past President*:—I trust, Mr. President, that you and the members of the Society will pardon a momentary interruption of the regular proceedings. I have received to-day a copy of a report made by the Shipping Committee to the National Foreign Trade Council on November 8. This report is signed by Mr. James A. Farrell, Mr. P. A. S. Franklin, and Mr. Robert Dollar, and it presents so clearly and so thoroughly the great problem facing this country in the utilization of the 11,000,000 gross tons of merchant

shipping now under creation by the Shipping Board that I venture to suggest that this report be printed as a part of the preliminary proceedings of this meeting, and that the Executive Committee be authorized to transmit copies of this report to all members of the Society.

THE PRESIDENT:—Is that motion seconded?

REAR ADMIRAL W. L. CAPPS, U. S. N., *Vice-President*:—I second the motion.

THE PRESIDENT:—The motion has been duly made and seconded that this report be reprinted by the Society, and a copy sent to each of the members. All in favor of the motion say "Aye"; contrary-minded, "No." The motion is carried.

REPORT OF THE COMMITTEE ON MERCHANT MARINE, NATIONAL FOREIGN TRADE COUNCIL. FIFTH ANNUAL MEETING, BILTMORE HOTEL, NEW YORK, NOVEMBER 8, 1918.

As the National Foreign Trade Council assembles in its Fifth Annual Meeting, the civilized world is alert with the hope that it has come at last almost to the threshold of re-established peace. The enemy's power of resistance is not yet wholly broken, and it may be that we shall be required to endure some months more of hard fighting and sacrifice before it collapses completely. But we are certain that it has been very greatly reduced and that it is destined in the not far distant future to full overthrow.

Concurrently with the restoration of peace there will confront the United States, as there will confront the other nations of the world, an array of weighty problems which, by common impulse, have been described as "problems of reconstruction." It is already clear what some of these problems will be. Others no doubt will manifest themselves only as conditions of actual peace develop. Many of them will be but variations in degree of problems with which we have labored throughout the war. It is clearly the part of wisdom and duty for all of us to make what preparation we can for the enduring solution of such of these problems as we now know are certain to confront us.

At the head of the list is the question of the Merchant Marine. Just as ships constituted the first problem of our participation in the war, so will ships constitute the first factor in our great task of reconstruction. It made no matter how many men we raised and equipped, or what supplies, what guns, what munitions, what airplanes and other paraphernalia of war we prepared. They were separated by nearly 3,000 miles of ocean from the place where they could render effectively the service for which they were provided, and without ships to transport them, they were all useless and a waste of effort. Thus ships have been the essential agency by which we have borne and are bearing our part in the struggle for civilization.

So, also, ships will be the essential agency through which we shall be enabled to do our full share in the work of reconstruction after the restoration of peace and in the development of our foreign commerce. And thereafter, ships—our own American ships—will be the essential agency through which we shall be able to maintain that just and beneficial relationship with the rest of the world to which our participation in the war and its prosecution to a successful close will entitle us and the rest of the world.

It is not only with us but with several others of the belligerent nations that ships will render vital service in meeting the problems of reconstruction. Our immediate reconstruction work will be different from that of France, Belgium, Serbia, Italy, Roumania, and the other war ravaged countries of Europe. It will be different even from that of Great Britain. First of all we must repatriate the millions of our men who have been sent abroad to take part in the fighting. For many months now they have been going overseas at a rate of between 250,000 and 300,000 a month—nearly 10,000 a day.

The first agency contributing to this marvelous result is our Navy. When the detail of the Navy's work in the troop transport movement can be told, the people of this country will have reason to be justly proud of the record. Every hope and expectation of the country has been fulfilled by this popular branch of the national service and there should go to it the fullest measure of credit.

This enormous embarkation of the American soldiers would have been impossible without the maritime co-operation of our Allies, especially of Great Britain. British vessels have transported about one-half of our soldiers.

This service rendered to us and to civilization by the British merchant marine has entailed a substantial interference with Great Britain's overseas trade. When the war ends it will find hundreds of thousands, and perhaps even millions, of British soldiers upon the continent of Europe. Great Britain, too, will have a problem of repatriation, necessitating the service of ships, but it will hardly be comparable in extent to our repatriation task.

The process of repatriation is not likely to begin for some time after the cessation of hostilities. Definite establishment of the peace conditions may require some delay. When it does commence it is probable that because of the rapidly increasing construction of American vessels, it will be possible to return more American soldiers per month, under their own flag, than were sent abroad in American vessels. And we should have the extensive aid of foreign vessels to minimize the time required for the return of our troops.

The troops of most of the belligerents, however, will be able to march or proceed by rail to their homes, and the redistribution of the men to their own places can be carried out much more rapidly, both by the Entente Allies and the Central Powers, than in our own case.

In the United States, Great Britain and the Central Powers—where the war has not wrought devastation and destruction of industrial plants—the immediate problem will be one of reconversion of plants from production of war material to the manufacture of peaceful merchandise, and the readjustment of labor so as to provide employment for the millions of men released from war service. In France, Belgium and the other war ravaged territories there will be added the enormously difficult problem of physical rehabilitation—the clearing away of ruins, the erection of new buildings, the equipment of plants with new machinery, and all the vast labor of the restoration of industrial and agricultural activity and production.

Thus, as far as the demobilization and readjustment of labor is concerned, all the other belligerent nations are likely to be able to progress more rapidly than the United States, and to that extent to devote themselves more promptly to the urgent problem of renewing their efforts in foreign trade. Great Britain will be able promptly to release a certain portion of her merchant fleet from war service, and to restore it to the commercial enterprises from which it has been diverted, although it will be necessary for her to accomplish fully the repatriation of her troops from her dominions and colonies. How soon, and to what extent, Germany will be able to resume overseas commercial operations under her own flag will depend very largely upon the final conditions of peace.

Freed from the menace of the submarine and from the restrictions of blockades and war zone regulations, the Dutch, Scandinavian, Spanish and other neutral merchant fleets will be enabled at once to render the highest service to their nations, in the rehabilitation and expansion of their overseas commerce.

Broadly, and in rough outline, that is the situation which will confront the United States upon the re-establishment of peace. It is fortunate for us that one of our greatest contributions to war work will also render a most valuable service after peace has been restored. We are building the ships which will be the most effective agency in the permanent solution of these great after-war problems. Always provided, however, that our nation adopts a definite maritime policy which will permit the permanent retention and operation of these vessels under the American flag. Just as the provision of ships has been and is absolutely first in importance in war winning service, so is the adoption of the correct national

maritime policy absolutely first in importance of the problems of peace already demanding solution at our hands. This important matter should be taken up by Congress at once to enable our shipowners and others interested to make the necessary arrangements to take our proper place in the world's commerce.

It is true that our vast enterprise of ship construction was undertaken essentially as a war measure, just as was the huge expansion of our production of guns and shells, and all the wide range of other war materials. But in the ships we are building there is a large element of permanent value for peace, as well as of war service. With the restoration of peace it is to be hoped that further need for guns and shells and other war supplies will be minimized, if not ended. But that fortunate date will mark the opening of a period of new and vital service to the nation for the ships we are now building as instruments of war.

The figures expressing the activities of the United States Shipping Board indicate the extent of the possibility of this new service. The National Foreign Trade Council has pointed out in previous reports dealing with this subject the fact that it was the experience of Great Britain, the greatest maritime power of the world during the last fifty years, that less than 60 per cent of British foreign trade is carried in British vessels. In ordinary times about 60 per cent of the carrying power of British shipping in foreign trade is employed in bringing imports into, and taking exports from, the United Kingdom, the remaining 40 per cent being engaged in trade between foreign ports. This shows the extent to which the shipping of a nation with a diversified foreign commerce must also be responsive to the demands of the commerce of the rest of the world. Great Britain's experience indicates that no nation with an extensive overseas trade will be able to transport all of its commerce in its own vessels, no matter how large and diversified may be its merchant fleet.

In 1915, 1,871,543 tons of American shipping carried 14.3 per cent of our total foreign commerce. In 1916, 2,191,715 tons of American shipping carried 16.3 per cent of our total foreign commerce. In 1917, 18.5 per cent of our total foreign commerce was carried in American vessels, but for war considerations, the official reports have not included the figures of the tonnage required for this transportation.

On the basis of an American merchant fleet of 10,000,000 gross tons estimated at a construction price of $75 per ton, a liberal estimate at pre-war rates, such a merchant fleet would cost $750,000,000. But construction costs have risen enormously during the war. Much of the new merchant fleet is constructed at costs well over $175 per ton, although no exact official figures have been published by the Shipping Board. If, however, the average costs were $200 per ton, the construction of a fleet of 10,000,000 tons would absorb only $2,000,000,000.

As a matter of fact Congress has appropriated $2,896,701,000 for the various purposes of the Shipping Board, chiefly for construction, and has authorized the incurrence of contract obligations to the extent of $945,549,000 in addition. The work of the Shipping Board has thus been financed to the extent of $3,842,250,000, and there is pending a request from the Board for further extensive appropriations. The Board submitted estimates to Congress for the current fiscal year aggregating $3,054,350,000, but Congress reduced these estimates by nearly $1,300,000,000 in making the appropriation. The program of the Shipping Board includes, of course, not only construction of ships under direct contract, but the completion of requisitioned vessels, the repair of seized enemy ships, the financing of shipyards for the fabrication of steel ships, a very large expenditure for the provision of houses for the workmen at the shipyards, and other large items not directly charged to con-

struction. From all this it is apparent that with construction costs of over $200 a ton and with appropriations for construction greater than $2,000,000,000 the resulting fleet will be materially more than 10,000,000 gross tons.

In a recent statement covering its work, the Shipping Board announced that its program included 2,249 contract ships, totaling 13,212,712 deadweight tons; 42 concrete ships, totaling 301,600 deadweight tons, and 402 requisitioned ships, totaling 2,790,792 deadweight tons, an aggregate of 2,693 vessels of 16,305,004 deadweight tons. This provides a fleet of approximately 11,000,000 gross tons, and does not include 100 seized enemy vessels of an aggregate gross tonnage of more than 425,000 tons additional.

On September 1st there were 2,185 vessels within the jurisdiction of the United States Shipping Board, aggregating more than 6,000,000 gross tons. Of these, 449 were requisitioned American merchant ships, 100 were enemy vessels seized during the war, 256 were new vessels owned by the Shipping Board, 31 were old lake steamers transferred to the Shipping Board, 377 were American merchant ships not yet requisitioned, 81 were Dutch ships requisitioned by the United States Government, and 891 were foreign ships chartered either to the Shipping Board or to American citizens. It will be observed that only a comparatively small part of this tonnage was provided by the Shipping Board program. Nearly half of it consists of foreign ships requisitioned or chartered, which may or may not remain in American service after the war. But 1,294 of these vessels of more than 4,000,000 gross tons in the aggregate fly the American flag and it is evident that the completion of the present program of the Shipping Board will add approximately 10,000,000 gross tons to the American merchant fleet. We shall have, therefore, a fleet roughly estimated at 14,000,000 tons at least, ample, on the basis of the British precedent, to meet the needs of our foreign trade.

There must be pointed out, however, the probability, if not the practical certainty, that a considerable proportion of this tonnage will be unavailable for off-shore service, especially under the conditions of competition which the new American fleet must meet. This refers particularly to the wooden ships which constitute so large a part of the Shipping Board construction program. It is, of course, well recognized that speed in construction has been a vital element in our provision of ships. This has tended inevitably to the increase of cost and, to a certain extent, to the decrease of efficiency. The expansion of shipyards, both in number and size, has been very great and very rapid. The supply of labor for these yards has unavoidably brought into service many thousands of men inexperienced in shipbuilding. Schools has been maintained for the instruction and training of workmen, and great effort has been made to increase the efficiency of the yards, but the best possible attainment has naturally been short of the standard of quality produced by experienced workmen in old-established yards and under more favorable conditions.

Every bit of service that such vessels can render now is, of course, highly helpful in the prosecution of the war, but the war itself operates to suspend conditions of competition which necessarily must be met by American merchant ships after the restoration of peace, and we must look forward to a certain reduction of the tonnage now included in the Shipping Board program, when peace conditions again become operative.

In view of these facts, your Committee suggests the advisability of curtailing the program of wooden construction at the earliest feasible date, and of the preparation to transform into barges the surplus of the wooden steamers over those which can be employed economically. The machinery thus made available could be used with advantage in steel hulls.

In August, 1917, there were only 61 shipyards in the United States. Of these, 37, with

162 ways, were building steel vessels, and 24, with 73 ways, were engaged in wooden construction. Today there are 203 shipyards in the United States: 77 steel, 117 wood, 2 composite and 7 concrete. Not all of them are yet completed, but 155 are finished, 35 more than half completed and only 13 less than half completed. There are 410 completed ways for steel ships, 400 completed ways for wood, composite and concrete construction, and 63 steel and 54 wood ways not yet completed. More than 385,000 employees are at work in these yards. The weekly payroll of the United States Shipping Board is more than $10,000,000. Two years ago there were fewer than 50,000 shipyard employees in the United States. This expansion is in the construction of vessels. There has been, of course, a corresponding development of the production of engines, machinery and equipment of vessels. There has been the development of an entirely new industry in shipbuilding, hitherto unknown in the world. It is the fabrication of steel vessels. The Shipping Board has promoted the erection of several vast yards for this method of ship construction, which alone are capable of producing more tonnage per year than could be turned out by the entire shipbuilding industry of the United States per annum prior to the war. It is inevitable that these organizations will constitute an important factor in American ship construction after the war, and in the permanent retention of an adequate merchant fleet under the American flag. The existence of a large body of labor trained in ship construction will constitute another important factor.

It is evident, then, that the restoration of peace will find the United States in possession of a merchant fleet much larger than that under the American flag at the outbreak of the war. That is true even if peace is restored in the very near future. The completion of the Shipping Board program, however, at least so far as the construction of steel vessels is concerned, will no doubt be effected, even though peace is promptly re-established, and if the war should continue another year, there may be even further expansion of this program.

While referring to the building program, it is most important to point out that the experience of the great maritime nations of the world has taught them that it is necessary to provide a certain proportion of passenger carrying steamers in their fleets. These steamers range from the small cargo passenger liners, carrying a few passengers, to the enormous high speed Atlantic liners. It is most essential, therefore, that our fleet comprise these various tyes of steamers in addition to cargo vessels.

A well-balanced fleet comprising all types of vessels, both passenger and freight, is essential if we are to compete successfully with the other maritime nations which already have all types of steamers. Nothing will foster in this country a maritime thought and spirit more than American passenger steamers ready to carry citizens to all parts of the world. The ships thus provided should equal or improve upon those of the present time if we are to take our rightful place as leaders in the merchant marine world.

It may be necessary to extend the program of steel construction in order to assist in making up for the depletion of world tonnage that has occurred during the war. Absolutely accurate reports of the extent of submarine destruction and normal marine losses are not now available. The Shipping Board has figured the total Allied and neutral losses for the period from August, 1914, to September, 1918, at more than 14,000,000 gross tons. It has estimated the total Allied and neutral construction during that period at approximately 10,000,000 gross tons. These figures indicate the present tonnage at something like 4,000,000 gross tons less than existed at the outbreak of the war.

But the world will need, at least for a considerable period after the re-establishment of peace, the services of a tonnage even greater than that which existed prior to the war, and

the merchant fleets now in being, even with the augmentation at present provided for by the construction programs of the United States and Great Britain, will be inadequate to the service they will be called upon to render.

It now seems probable that it will require the continuation of the present accelerated program of construction for a considerable time after the war, in order to bring the world's ocean tonnage again to the point where it is adequate to meet the world's needs.

The United States, then, will emerge from the war with a large merchant fleet and with the facilities for its renewal and expansion, but unless positive steps are taken in the very near future toward the formulation and adoption of a sound national maritime policy, it may be set down as absolutely certain that these newly constructed American vessels will not remain in operation under the American flag and that the American merchant marine, rehabilitated with vast expenditure of capital and effort as a war emergency measure, will again be dissipated under the operation of inexorable economic laws.

For one thing is absolutely sure: Unless these vessels can be operated profitably under the American flag, either they will be transferred to foreign registry or they will rust out a useless existence which will soon terminate on the scrap heap. For production is fundamentally a question of profit, and production of ocean transportation, especially in foreign trade, where we must meet the competition of the world's ships, is not differentiated in its amenability to this economic law from the production of cotton or lumber or any other of the myriad articles of our daily commerce.

It is true that Congress has enacted a law forbidding the alienation of any American vessel without the consent of the United States Shipping Board, but neither that law nor any other of similar character will keep any American vessel in operation or prevent barnacles from growing on its hull unless conditions are such that it can be operated under the American flag at a profit for those who are operating it.

The American national maritime policy, therefore, which is to provide for the permanent retention and operation of our new merchant fleet under the American flag, must be founded upon the principle that those operating the vessels shall be assured of conditions which will enable them to meet the competition of all other maritime nations upon an equitable basis.

As your Committee has pointed out in previous reports, the law creating the Shipping Board recognizes the wisdom of operating the vessels of the new fleet through private enterprise. It provides that upon the termination of a fixed period after the re-establishment of peace the Board itself shall not undertake the operation of any vessels until after a bona fide effort to sell, lease or charter such vessels has failed. It is obvious at once that any bona fide effort to sell, lease or charter must take into account the exceptional element of war cost and war service. The Chairman of the Shipping Board has publicly recognized this in an address in which he said:

"They [these ships] are being constructed because, and only because, of war needs, under conditions and pressure which have enormously increased their cost per ton over the cost of construction prevailing in normal times. It would seem fair that their valuation be written down to a point which will give them a fair chance to compete with vessels built before the war at much lower cost."

The merchant fleet provided by the program of the Shipping Board will represent at the conclusion of the war an expenditure by the United States of approximately $4,000,000,000. It is obvious that if private enterprise, in order to undertake the operation of these vessels

under the American flag, is to be required to invest the full amount of that huge sum, it will not make the attempt. Manifestly the correct procedure is that indicated by the Chairman of the Shipping Board in his suggestion that the valuation of the vessels be written down, and that a portion of their cost be charged off to war service. This procedure would be eminently just, as well as absolutely necessary to the permanent retention and operation of these vessels under our flag. The war service rendered by these vessels is of the highest character, not second even to that of the guns and shells which they transport to the theater of war. But the guns and shells are wholly written off. Their entire cost is charged to war service. Whatever valuation may be determined upon ultimately as fair and just, these ships will represent a recovery of expenditure for the Government impossible in the case of vast disbursements for munitions.

Broadly speaking, there are three essential factors in the furnishment and operation of ships: the cost of capital, the cost of construction and the cost of operation. As far as the first is concerned, the United States will certainly be in no worse position than foreign countries after the war. The probability is that we shall be in better position than some, at least, of the nations which will be interested in expanding their maritime enterprises. Private enterprise will be able to obtain at reasonable cost the capital necessary to extend its investment in merchant vessels. But private enterprise will not care to expand its investment in that direction unless there is reasonable assurance that it will be permitted to operate at a profit any vessels which it may purchase, lease, or charter, and unless it has reasonable assurance that costs of construction will be such that renewals or additions to its fleet may be obtained upon terms which will permit competition with foreign fleets upon an equitable basis.

For reasons already referred to, it seems likely that American shipyards after the war will be able to produce tonnage at the rates and under conditions that will compare favorably with those obtaining in foreign maritime countries. It is therefore in the third factor—costs of operation—that there are most likely to be found the disadvantages to American enterprise which will constitute the greatest obstacle to the continued successful operation of our new vessels under our own flag. These obstacles are found in certain provisions of our existing navigation system, the inevitable result of which is to increase the costs of operation to the disadvantage of American maritime enterprise.

No one contends or believes that it is not desirable to have American vessels fully manned by competent crews and to have American seamen enjoy the best possible conditions of life and service, and receive in wages due and ample return for their labor. But it is perfectly obvious that provisions of law which require American vessels to maintain larger crews, and to pay them higher wages than is the case with foreign vessels, necessarily subject such American vessels to a disadvantage which renders it difficult if not impossible for them to continue in operation against the competition of foreign vessels which can operate at lesser costs.

Your Committee again draws attention to the vital necessity of an early and thoroughgoing revision of the American navigation system which shall strip it of its present inequalities and injustices if the merchant fleet now in process of creation as a war emergency is to be retained in operation under the American flag. Attention is again called to the fact that the law creating the United States Shipping Board directed the Board to conduct an examination into comparative costs of construction at home and abroad; an examination into systems of classification at home and abroad; an examination into the question of marine insurance; and an examination of the American navigation system, with a view to submitting recommendations to Congress covering its amendment, revision and improvement.

It has been suggested that the derangement of normal conditions resulting from the war has rendered difficult—even impossible—the practical performance of some of these tasks, such as the examination into comparative costs of construction and the examination into comparative costs of operation. Your Committee suggests, however, that a vast amount of valuable information is available as to conditions obtaining prior to the war, and which may be approximated again not long after the restoration of peace. Your Committee suggests also that no obstacles have been created by war conditions which render impractical the present performance of the investigations into the subject of marine insurance and the American navigation system ordered by Congress. Furthermore, the information to be developed by these investigations is of the utmost importance in the formulation of the fundamental national maritime policy, which is an absolutely essential prerequisite to the permanent retention and operation of the New American merchant fleet under the American flag.

We cheer the acquisition of the new fleet and we applaud the energy of the Shipping Board and the tireless industry of the thousands of workmen in the mills and shipyards who have brought it into being; but our cheers will be idle and our enthusiasm and energy will have been wasted unless before the day arrives for the renewal of competition that is bound to follow the restoration of peace we have formulated and adopted a policy based upon honest recognition of fundamental economic principles, which will enable us to meet that competition with our new American ships, under the American flag, with honor and with profit to ourselves and without injustice or unfairness to our competitors. It is most important that the American should face his competitors under equal conditions. All that is needed is a fair field and no favor. As an incident of the international agreement and settlements soon to be worked out, the maritime nations should agree upon uniform regulations which will impose equal conditions and requirements upon all alike. Such an arrangement would insure that equality which will give every one a fair chance.

Respectfully submitted,

James A. Farrell,
P. A. S. Franklin,
Robert Dollar.

The President:—We will now have papers Nos. 9 and 10. We will have them read and then discussed together. The first is No. 9, entitled "Experiments upon Simplified Forms of Ships," by Prof. H. C. Sadler, Member of Council, and Mr. T. Yamamato, Visitor.

Professor Sadler presented the paper.

EXPERIMENTS ON SIMPLIFIED SHIP FORMS.

By Professor H. C. Sadler, Member of Council, and T. Yamamoto, Esq.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

The question of the simplification of ship forms is one that has received a good deal of attention during the past year. In their anxiety to produce a simple form from a structural standpoint, a good many designers, not familiar with ships, have ignored entirely the question of economical propulsion.

During the past year some experiments upon "straight frame" forms have been conducted in the tank at the University of Michigan, and the results are thought to be of sufficient interest to place the same on record.

The main object of the experiments was to determine what difference in resistance existed between an ordinary shipshape form and one in which the curved form of the frames was replaced by straight lines. No particular attempt was made to develop the best possible form, but the main features of the two types were kept constant.

The diagonal line representing the corner was in all cases made a straight line, with the view that, if the bilge corner were cut off, this would facilitate construction.

MODELS.

The body plans shown in Figs. 1, 2, 3, 1a, Plate 86, represent the various forms used. The models were 10 feet long and 16 inches wide. For each particular type the following characteristics were kept constant, viz., length, breadth, draught, displacement (at load draught, with the corner cut off); the curve of sectional areas (and hence prismatic coefficient), and the shape of the waterline.

The models were tested at three different draughts covering the usual range.

In each case the model was first tried with the sharp corner, and latterly this was removed.

Two different slopes were given to the bilge diagonal to determine the effect of this feature.

In one case also the lower knuckle was given a small enough slope to keep it within the double bottom, the top knuckle in this case remaining the same as in form (Fig. 1, Plate 86).

The following table gives the characteristics of all the forms tried:—

Draught	B/d		0 per cent	10 per cent	20 per cent
		Y. 1 (corner off)			
7″	2.285	Long. Coeff.	.674	.707	.739
		Block Coeff.	.655	.688	.718
		Mid. Coeff.	.973	.973	.973
		Water Line Coeff.	.760	.784	.808
6″	2.66	Long. Coeff.	.662	.697	.728
		Block Coeff.	.641	.675	.706
		Mid. Coeff.	.969	.969	.969
5″	3.2	Long. Coeff.	.646	.681	.716
		Block Coeff.	.621	.655	.688
		Mid. Coeff.	.962	.962	.962
		Y. 2 (corner off)			
7″	2.285	Long. Coeff.	.674	.708	.739
		Block Coeff.	.655	.688	.718
		Mid. Coeff.	.973	.973	.973
		Water Line Coeff.	.760	.784	.808
6″	2.66	Long. Coeff.	.662	.697	.729
		Block Coeff.	.641	.675	.706
		Mid. Coeff.	.969	.969	.969
5″	3.2	Long. Coeff.	.646	.683	.716
		Block Coeff.	.623	.659	.691
		Mid. Coeff.	.965	.965	.965
		Y. 3			
7″	2.285	Long. Coeff.	.673	.706	.737
		Block Coeff.	.655	.688	.718
		Mid. Coeff.	.974	.974	.974
		Water Line Coeff.	.760	.784	.808
6″	2.66	Long. Coeff.	.661	.696	.728
		Block Coeff.	.641	.675	.706
		Mid. Coeff.	.970	.970	.970
5″	3.2	Long. Coeff.	.647	.683	.718
		Block Coeff.	.623	.658	.692
		Mid. Coeff.	.964	.964	.964

Draught	B/d		0 per cent	10 per cent	20 per cent
		Y. 1 (with corner volume)			
7″	2.285	Long. Coeff.	.673	.706	.737
		Block Coeff.	.660	.693	.724
		Mid. Coeff.	.983	.983	.983
		Water Line Coeff.	.760	.784	.808
6″	2.66	Long. Coeff.	.661	.696	.728
		Block Coeff.	.647	.682	.713
		Mid. Coeff.	.979	.979	.979
5″	3.2	Long. Coeff.	.644	.679	.712
		Block Coeff.	.628	.662	.694
		Mid. Coeff.	.975	.975	.975
		Y. 2 (with corner volume)			
7″	2.285	Long. Coeff.	.672	.706	.737
		Block Coeff.	.659	.694	.724
		Mid. Coeff.	.983	.983	.983
		Water Line Coeff.	.760	.784	.808
6″	2.66	Long. Coeff.	.660	.695	.728
		Block Coeff.	.646	.680	.713
		Mid. Coeff.	.979	.979	.979
5″	3.2	Long. Coeff.	.646	.679	.716
		Block Coeff.	.630	.662	.698
		Mid. Coeff.	.975	.975	.975
		Y. C.			
7″	2.285	Long. Coeff.	.674	....	.738
		Block Coeff.	.656	....	.718
		Mid. Coeff.	.984	....	.984
		Water Line Coeff.	.760	....	.808
6″	2.66	Long. Coeff.	.661	....	.729
		Block Coeff.	.641	....	.706
		Mid. Coeff.	.969	....	.969
5″	3.2	Long. Coeff.	.644	....	.715
		Block Coeff.	.620	....	.688
		Mid. Coeff.	.963	....	.963

The fuller models, marked 10 per cent and 20 per cent, were obtained from the finer forms by adding 10 per cent and 20 per cent middle body and contracting the form of the ends to keep the length constant.

The curves of sectional areas and load waterline are shown in Figs. 4 and 5, Plates 87 and 88, and in connection with the latter it will be noticed that, in order to use the same form in all cases, this necessitated a somewhat fuller line forward than was compatible with ease of propulsion. For purely comparative purposes it was deemed advisable to keep the same waterline throughout.

The general results are summarized in the curves (Figs. 6, 7 and 8, Plates 89, 90 and 91). A comparison of each set of curves for each type shows that the ship-shape is the best, and that, of the other two forms with the corner off, the one with the steeper slope to the bilge diagonal gives better results than where this is at a smaller angle.

At the lower speed-length ratios there is little, if any, difference, and such as there is is of the order of 1 to 2 per cent.

The effect of retaining the sharp corner appears in all cases to increase the resistance somewhat as shown in Figs. 9 and 10, Plates 92 and 93, *i. e.*, the resistance increases at a somewhat more rapid ratio than the added wetted surface.

The remaining form with the lower knuckle line dropped (Fig. 1a, Plate 86) shows slightly more resistance than the best of the other forms, but the amount is small; in fact it seems to lie between the first two forms.

SERIES 2.

A similar set of tests was carried out upon a model of fuller form. In this case the curve of sectional areas was changed to one suitable for this type. The body plans are shown in Figs. 11 and 12, Plate 94. The particulars of the models are given in the following table:—

Draught	B/d	Coefficient	Y. 1 C. corner-off	Y. 3 C.	Y. 1 C. with corner volume
7″	2.285	Long. Coeff.	.801	.798	.801
		Block Coeff.	.779	.779	.785
		Midship Coeff. ..	.973	.976	.981
6″	2.66	Long. Coeff.	.791	.788	.791
		Block Coeff.	.766	.766	.773
		Midship Coeff. ..	.968	.972	.978
5″	3.2	Long. Coeff.	.780	.778	.780
		Block Coeff.	.749	.750	.759
		Midship Coeff. ..	.961	.965	.974

The results of the tests are shown in Fig. 13, Plate 95, and in general are of the same character as in the previous series.

The effect of retaining the corner volume at the bilge is to increase the resistance about 3 to 4 per cent, or approximately the same as that due to the added surface.

Compared with the shipshape form, there is practically no difference in resistance between this and the simplified form with the corner cut off.

Although time did not permit of carrying out a complete set of rolling experiments, some of the models were tried and it was found that the effect of the sharp corner upon the reduction of rolls was most marked, and that even with the corner removed these models came to rest quicker than the shipshape form.

The general conclusions that may be drawn are as follows:—

1. Vessels of the straight frame type can be designed which will have about the same resistance as a shipshape form.

2. If the diagonal line of the corner be given the wrong slope, this will increase the resistance due to the lack of conformity with the proper stream line flow.

3. The effect of maintaining the square corner is to increase the bare hull resistance, but as vessels of this form would not need bilge keels the net result from a horse-power standpoint would be about the same as for a shipshape form.

4. Probably the best results from a resistance standpoint would be obtained by using diagonal line which is of a curved form in the body plan.

DISCUSSION.

The President:—We will now have paper No. 10, entitled, "Variation of Shaft Horse-Power, Propeller Revolutions and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single Screw Cargo Ship," by Commander William McEntee, Naval Constructor, U. S. Navy, Member.

Let me say, gentlemen, that it is not our fault in any way that the copies of the papers were not received in time for your examination previous to the reading. Copies were distributed by mail to our members, and the copies for distribution here were sent by express from Washington several days ago. One of two things happened, either that they were not properly shipped—which I do not believe to be the case—or the Director-General of Railroads and Express Companies is not "on to his job."

Commander McEntee then presented his paper.

VARIATIONS OF SHAFT HORSE-POWER, PROPELLER REVOLUTIONS, AND PROPULSIVE COEFFICIENT WITH LONGITUDINAL POSITION OF THE PARALLEL MIDDLE BODY IN A SINGLE-SCREW CARGO SHIP.

By Naval Constructor William McEntee, U. S. N., Member.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

Previous experiments made at the U. S. Experimental Model Basin indicate* that for slow ships of full lines, such as are used for the ordinary single-screw cargo ship, it is desirable to use a certain amount of parallel middle body. In those experiments the different models used had varying lengths of parallel middle body distributed equally forward and abaft the midship section. The present investigation had for its object the determination of the best fore and aft position for the parallel part of the ship, and the investigation of the effect of this variation on the shaft horse-power, propulsive coefficient, and wake and thrust deduction factors.

Four 20-foot models were made corresponding to ships of 400 feet length between perpendiculars and of 57.3 feet beam, 26 feet draught, and 13,137 tons displacement when fully loaded. A longitudinal or prismatic coefficient of 0.788 was chosen as representing about the present practice in cargo carriers of this type. A constant length of the parallel middle body was taken equal to 33 per cent of the ship's length. This percentage was found in the investigations referred to above to give about the minimum residuary resistance for the speeds attained in practice for ships of this type.

In Fig. 1, Plate 96, are shown the lines of model 2,023 which were used as the parent form. In Fig. 2, Plate 97, are shown the curves of sectional area for the four models and the parent form. Model 2,132 was made very full at the entrance, with a fine run. Model 2,135 was made relatively very fine at the entrance and full in the run. Models 2,133 and 2,134 were intermediate between the two extreme models. The model with the very full bow and that with the very full stern were purposely made of an extreme type beyond anything that might be expected to be used, in order to give a wide scope to the investigation and to insure that the limiting condition as regards power should be obtained at either extreme.

In the four models the middle section of the parallel middle body—that is to say, the section which divided the parallel middle body into two equal portions—was placed at varying distances from the forward perpendicular, amounting to 31.3, 38.5, 53.4, and 60.5 per cent of the length of the ship, respectively.

*"Speed and Power of Ships," by D. W. Taylor.

The models were carefully made and all were fitted with the same cast stern frame, which included the stern bearing for the propeller shaft. The stern frame had the rudder cast with it. The whole frame and rudder was fitted to each of the four models before the self-propulsion experiments were undertaken, and, together with the propeller shaft, propeller, and dynamometer, was transferred from one model to the other as the experiments with each model were completed.

The dynamometer consisted of a small direct-current motor, the armature shaft of which was directly connected with the propeller shaft by means of a flexible coupling. The armature shaft was free to float fore and aft in its bearings about 7/16 inch in an axial direction. The armature shaft was connected to a calibrated spring by means of a thrust bearing, so that the axial displacement of the armature shaft gave a measurement of the propeller thrusts. Similarly, the frame of the motor was mounted so as to rotate in independent bearings. The torque developed by the motor acted against a calibrated spring so that the deflection of the spring indicated the torque of the motor. In addition to this there were suitable means provided for measuring the revolutions of the shaft.

The order of procedure in making the tests was as follows:—The shaft and dynamometer were carefully lined up and the whole run for a sufficient time to warm up the bearings and reduce the bearing friction as much as possible. Owing to the fact that the dynamometer was placed very close to the stern, but a short length of propeller shafting was necessary, and this was supported by two self-aligning bearings, one at the stern bearing and the other at the forward end of the stern tube. With the propeller shaft in place and everything working freely the model was towed in the Model Basin beneath the towing carriage at several different speeds, and the propeller shaft, without propeller, run at the range of revolutions to be covered in the course of the experiments. The propeller was then fitted to the shaft and cards for torque and thrust and revolutions per minute were taken with the model self-propelled at different speeds. In these tests the model was guided by two plates about 10 inches in width placed at either end of the model, so as to steer it in a straight course. The guide plates floated between the guilding points attached to the carriage, but the towing carriage did not exercise any force on the model in a fore-and-aft direction. Starting at low speeds corresponding to about 5 knots for the ship, the towing carriage was adjusted to run at a uniform speed. The rheostat controlling the speed of the propeller dynamometer was then adjusted so that the thrust of the propeller would just keep the model running as fast as the towing carriage, without striking the stops, which were placed at an interval of 6 inches. Thus, starting with the model in the mid position, it was free to gain or lose a distance of 3 inches as compared with the towing carriage before striking either stop. When the propeller was running at the proper speed to keep the model up with the towing carriage the record of thrust, torque and revolutions per minute was taken. If, in the course of the run, the model struck either stop on the carriage the run was discarded and another run made. Having obtained the desired data at the lowest speed, the carriage speed was increased for subsequent runs and similar data taken at higher

speeds. The range covered corresponded to speeds of 5 to 12½ knots for the ship. About forty different runs were made with each model, giving a corresponding number of points for plotting the torque, thrust, and revolutions per minute curves.

The armature of the propeller dynamometer was especially designed to reduce to a minimum the amount of magnetic thrust. This thrust increased with the torque and amounted to 0.17 pound when the armature was displaced 7/16 inch and the torque delivered to the shaft was 16 pounds-inches. Neglecting this at higher powers would have caused an error in thrust measurements of about 1.4 per cent, but would not have caused any error in the power measurements. However, this magnetic thrust was separately calibrated, and corrections for it were made in working up the results of the experiments.

It is interesting to note that experiments of this kind with a very heavy model, in this case a displacement of 3,774 pounds, afford a very sensitive means of checking the uniformity of speed of the towing carriage. If the towing carriage itself were not very carefully adjusted, so as to eliminate slight variations in power required to drive it, owing to variations in the level of the tracks or uneven friction of the driving wheels or guide wheels, the resulting small accelerations and retardations of the carriage were made very apparent. As the model, driven by its own propeller, when supplied with a constant voltage, ran at very uniform speeds, it was possible to see the towing carriage gaining or losing distance of a few inches in five or ten seconds, as slight inequalities of speed due to small variations in the resistance of the driving mechanism developed. In order to conduct self-propulsion experiments successfully with the method followed, it was necessary to have the towing carriage running in excellent condition.

Immediately after completion of the self-propulsion tests on the model the propeller was removed and the runs to obtain the shaft friction and the thrust without propeller were repeated. The model was next connected with the resistance dynamometer on the towing carriage and the usual model resistance data taken. This insured that the conditions of test both for self-propulsion and for the resistance of the model would be uniform as regards conditions of the model, temperature of water, etc. Experiments on the four models were run on succeeding days, and the springs of the propeller dynamometer were calibrated both before and after the tests.

In Fig. 3, Plate 98, is shown one of the dynamometer cards taken for a model running at a speed corresponding to about 10½ knots for the ship. It will be noted that the deflection of the torque spring for this condition was 2.47 inches, for the thrust spring 2.24 inches, and the interval over which the revolutions were measured was 1.78 inches. With a little practice it was possible to read both the thrust and the torque deflections within 1/100 of an inch. The revolutions could be read to an accuracy of less than one-half of one per cent. Considering that the data taken are plotted and the whole averaged by means of faired curves, it is estimated that the results obtained as regards the three elements measured are correct within one per cent.

In Fig. 4, Plate 99, are shown the actual observations of the torque and thrust pen deflections, and the revolutions per minute of the propeller shaft plotted on speed of the model, the latter being measured by the speed of the towing carriage in the same manner as in the ordinary resistance tests.

The following are the dimensions of the propeller used in the experiments and also the dimensions expanded to the ship scale:—

	Model	*Ship*
Diameter	10.125″	16′ 7″
Pitch	9.0″	14′ 9″
Pitch ratio	0.889	
Mean width ratio	0.20	
Number of blades	3	
Ratio of projected to disc area	0.266	
Blade thickness fraction	0.04	

The propeller had three blades of Taylor's standard form.

The propeller characteristics were obtained by separate tests of the propeller model run in free water, that is, in a separate apparatus where the propeller shaft projected well ahead, so that the propeller ran in water undisturbed by the action of the testing apparatus. The same motor dynamometer was used for the tests as was used for the self-propulsion tests, the only difference being that the propeller shaft was coupled to the forward end of the armature shaft instead of the after end.

The characteristics of the propeller are given in Fig. 5, Plate 100. The thrust constant, C_T, and the torque constant, C_Q, are plotted on nominal slip following the method used by Schaffran.* These constants, which are in non-dimensional form, lend themselves well to the analysis of self-propulsion experiments and to the extension of the results to the full-size ship.

The results of the investigation are given in Figs 6, 7, and 8, Plates 101 to 103. An examination of the effective horse-power curves and the shaft horse-power curves for the different models shows, as would be expected, a wide variation in power required. By plotting cross curves of power at a speed of 11 knots it will be found that, for both the effective horse-power and the shaft horse-power, the best results are obtained when the middle section of the parallel middle body is placed about 43 per cent of the ship's length from the forward perpendicular. But 2,000 shaft horse-power is required for the ship represented by model 2,133 at a speed of 11 knots. This is considerably below that obtained with the ordinary 400-foot cargo ship of this displacement and may possibly be questioned as to whether it is not lower than could be expected to be obtained on a real ship. It must be remembered, however, that the lines are of good form and the friction of the shaft has been eliminated, so that the powers given do not include shaft friction. As to the

*"Systematische Propellerversuche;" K. Schaffran, Schiffbau, September 22, 1915.

reliability of the method followed it may be stated that in similar experiments made on a model of the twin-screw collier Jupiter, for which are available accurate trial data, the results of the model tests, when extended to the ship, agreed identically as regards the propeller revolutions and within one per cent as regards power and propulsive coefficient.

In Fig. 8, Plate 103, are shown the curves of wake fraction, thrust deduction coefficient, apparent slip, and true slip for the ship. In extending the results of the model experiments to the full-size ships it has been assumed that the wake fraction and thrust deduction coefficient for the ships are the same as for the models. The apparent slip and the true slip for the ship are less than for the model, because of less relative resistance, owing to the fact that the frictional resistance increases less rapidly than if it followed the law of comparison.

In order to avoid confusion in terms the following definitions of thrust deduction coefficient, t, and wake fraction, w, are given:—

$$t = \frac{T-R}{T}; \quad w = \frac{V-V'}{V},$$

in which T is the thrust of the propeller, R the resistance of the ship, V the speed of the ship, V' the speed of advance of the propeller in the water in which it works.

As was to be expected, the wake fraction and thrust deduction coefficient both increase with fullness of the stern. It is interesting to note that in all cases the wake fraction is considerably greater than the thrust deduction coefficient, resulting in a hull efficiency greater than unity. The wake fraction obtained for the different models at a speed corresponding to eleven knots for the ship varies from 0.29 to 0.35.

The formula for wake fraction given by Taylor is as follows:—$w = -0.05 + 0.5b$, in which b is the block coefficient. This would give for all of these models a wake fraction of 0.336. The average of the results obtained in these experiments is 0.31, which is but slightly less than that estimated by the above formula.

DISCUSSION.

The President:—These two papers, No. 9, entitled "Experiments upon Simplified Forms of Ships," and No. 10, entitled, "Variation of Shaft Horse-Power, Propeller Revolutions and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single-Screw Cargo Ship," are now open for discussion. These papers are particularly interesting and will be discussed together. We will be glad to hear from anyone in the room.

Constructor-Commander S. V. Goodall, R. N., *Member*:—Mr. President and gentlemen, it has been my privilege, during my stay in this country, to spend some little time at the U. S. Model Basin in Washington, and to see these experiments, or experiments similar to them, carried out by Commander McEntee. I was very much impressed with the sys-

tem adopted in measuring the hull efficiency elements, because it is entirely different to that employed in Great Britain.

I had an interesting correspondence with Mr. R. E. Froude of the British Admiralty Experiment Works on the subject, and he thought that the difference between the two systems could be summed up as follows:—In Great Britain the character of the investigation was such as to obtain definite measurements of discrete parts, whereas in America the system was directed towards measurements of concrete wholes. That is, perhaps, criticism of a somewhat theoretical nature and, for my part, I was particularly impressed with the American system of measuring the hull efficiency elements. I should like to see, and hope I shall see, when I return to England, experiments made on these lines and the results compared with those made according to the practice in our country.

I may say that Commander McEntee's deduction as to the advantages and disadvantages of the full and fine stern agrees with some of the actual results we have had with ships differing in fullness of stern, but otherwise similar, designed and built in Great Britain during the war.

With regard to Professor Sadler's paper experiments were carried out in Great Britain on simplified forms, and a form was developed by the Director of Naval Construction at the Admiralty that gave results similar to those stated by Professor Sadler, viz., that a simplified form can be designed with practically no increase in resistance over a form of the ordinary type. These results were communicated to the United States Navy Department and the Shipping Board, and experiments were made at Washington, which, I understand corroborated the results obtained in England.

I do not believe the results of the British experiments have been published, and it may be of value to have them forwarded for insertion in the transactions of this Society. I should have great pleasure, if you wish, in writing to Sir Eustace D'Eyncourt and asking him if he will agree to the insertion of these results in the transactions of this Society.

The President:—We shall be very glad to have these figures. Is there any other gentleman who wishes to discuss these papers or either one of them?

Mr. Alfred J. C. Robertson, *Member:*—Mr. President and gentlemen, it is very encouraging to discover that, in the rush of war work with which we have been overwhelmed in the last eighteen months, some gentlemen have been able to give their careful thought to the design of ships to meet after-the-war problems. The two papers presented to us by Professor Sadler and Commander McEntee represent an enormous amount of work.

In connection with Professor Sadler's paper on the simplified ship forms, I might say that it represents the making of probably thirteen models, and then modifying the thirteen models to perhaps get twenty models in all. These twenty models have been tested in each case at three different drafts and probably twenty or thirty runs were given for each model, so that you see the amount of work is very great and the paper does not bring that out without careful study.

I had the pleasure of looking into some of the figures given here, and the results, in my opinion, are quite worth calling your attention to. Two types of models were tested; the first type was for a fine model and had three parallel middle bodies. Results are given without parallel middle body, and with 10 per cent and 20 per cent of parallel middle body inserted. In the results the box form shows an average of 2.4 per cent more resistance than the straight frame model with the corner cut off diagonally.

A very curious thing is that the model with the corner cut off actually shows less resistance than the shipshape form for quite a range of speeds in each case. The difference in resistance, however, amounts to only about 1 per cent below and about 2 per cent above the resistance of the shipshape model. Now, when putting the two facts together, the box-shaped model has a resistance approximately of 3 to 3.5 per cent above the shipshape. The bilge keels added to the shipshape model would account for 2.5 to 3 per cent in resistance, so that the box-shaped model and the shipshape model would be practically identical in resistance.

There is one other important point in regard to these model tests for the finer models. Professor Sadler has given us the curve of sectional areas and the curve of load-water plane—the outline of the load-water plane, for each model—and you will notice, as a basis for the tests, that a certain model tested at the British National Tank was used, but there is some departure in the outline of the load-water plane.

I compared the results of Professor Sadler's tests with the results published of these British tests, and I was very much astonished to find the result of this slight difference in the outline of the load-water plane forward. The resistance was actually increased for the Sadler models by about 20 per cent. That happens in these finer models where hollow water lines are necessary. In the full model, I may say that it does not occur, and the full model shows up wonderfully well.

In regard to Commander McEntee's paper, I have only had time to glance at it, but it well deserves the most careful study. I have, however, made a comparison between Professor Sadler's full model and Mr. McEntee's model. Mr. McEntee's model is 0.789, I think, in prismatic coefficient. Professor Sadler's model was 0.801 prismatic coefficient, but there is a slight difference in the way the prismatic coefficient was taken—the aperture is included in Mr. McEntee's figures, so that the two models are practically identical. If we reduce the square box-shaped model of Professor Sadler to the dimensions of Mr. McEntee's ships, having the same displacement and the same draught ratio, we find that the minimum resistance, taking a cross curve on Mr. McEntee's four models, shows 1,880 shaft horse-power at 11 knots and Professor Sadler's model Y1C shows 1,930 with a square bilge, assuming the same propulsive efficiency. That shows that there has been a loss of 50 horse-power only in the square bilge model, over the best results of these four models—as a matter of fact, the very best comes between Mr. McEntee's model No. 2133 and model No. 2134, and falls almost exactly on model No. 2023, which, by the way, is a model based on results published by the British National Tank.

There is one question I would like to ask Mr. McEntee, and that is in regard to the slip. He has not defined it sufficiently clear for me to know just what he means. There is the apparent slip and the true slip. Do these slips refer to the effective slip measured without correction for wake, or do they refer to the face slip measured with and without the wake correction?

I wish, personally, to thank the gentlemen who have presented these papers.

The President:—We have some written discussions on these papers which will appear in the proceedings. Time does not permit us to have them presented in full at this period.

Professor W. Hovgaard, *Member* (Communicated):—I consider Professor Sadler's and Mr. Yamamato's experiments very important and interesting. I have long been under

the impression that the "straight frame" construction with a sharp knuckle line amidships would be advantageous, especially in ships with a parallel middle body; that is, that the increase in resistance to propulsion would be so small that it could be disregarded in comparison with the gain due to simplified construction. In 1909 I suggested this form of hull in Jane's "Fighting Ships" for battleships with external bottom armor where fitting of the heavy plates on the round turn of bilges would present special difficulties, but I did not contemplate continuing the knuckle line much beyond about one-half of the length of the ship. I was, however, prepared to find that the increase in resistance due to this feature might be prohibitive in ships of such high speed-length ratios and such form as found in modern battleships.

The experiments of Professor Sadler and Mr. Yamamato throw much light on this problem, and seem to show that in cargo vessels with speed-length ratios smaller than 0.9 the increase in resistance by this construction is on the whole insignificant, and that the adoption of the "straight frame" type seems well worth serious consideration. Perhaps it will be found most advantageous to adopt the square corner and to stop the knuckle a little beyond the parallel middle body.

It would be of interest to carry the investigation a step further and to determine the resistance of a ship form approaching even more closely to a pure flatiron shape. The form I have in mind is one by which the knuckle line lies in a horizontal plane and where the floors have a uniform but small rise from end to end, making the corner angle a little larger than a right angle. The bottom would then be almost quite flat, formed of two plane surfaces, slightly inclined upwards from the kee on either side. Some flare should, of course, be given to the sections in the bow and in the stern, and locally, some deviation from the simple form would probably be necessary in way of the propellers and the rudder, but practically all the plates in the bottom would be plane or developable with a slight twist, and the frames would be straight with only one knuckle. If experiments on such a ship form have not already been made, it would seem worth while to make them and to investigate whether the gain in the first cost of construction would be outweighed or not by the increased resistance to driving.

Rear Admiral D. W. Taylor, U. S. N., *Vice-President* (Communicated):—The paper by Commander McEntee breaks new ground and affords another illustration of the value of the apparatus for investigating wake, thrust deduction and propulsive efficiency which has been installed at the Model Basin by Commander McEntee. It seems to me that this very interesting paper gives another illustration of what is, I believe, the fact, namely, that there are many cases where a careful model basin investigation of a low-speed ship discloses that there is a greater field for improvement than in the case of high-speed ships, although we all know that, as regards the latter, the last word is far from said.

The propeller tried is seen in Fig. 5, Plate 100, to have a maximum efficiency somewhat greater than 70 per cent. Although the author does not give us the hull efficiencies, he states that they are greater than unity, as might be expected and as is evident from inspection of Fig. 8, Plate 103. With the maximum propeller efficiency of over 70 per cent, and the hull efficiency greater than unity, making the maximum possible propulsive efficiency well over 70 per cent, we find in Fig. 7, Plate 102, the maximum propulsive efficiency is only about 65 per cent. The reason is very simple. We find in Fig. 8 that, although the apparent slip at 10 knots averages, roughly, about 15 per cent, the true slip averages over 40 per cent, and at 40 per cent slip the efficiency of the propeller, instead of approaching its maximum

value of over 70 per cent, is only about 60 per cent. In other words, the propulsive efficiency is about 20 per cent below what would be obtained from a well-proportioned propeller working under conditions favorable to high efficiency.

There is an enormous field for improvement here. A little investigation will disclose the fact that it is practically impossible to get satisfactory propeller efficiencies from large, slow vessels unless the revolutions are kept very low and propellers made as large as possible. With reciprocating engines, of course, low revolutions mean a great increase of weight and cost of machinery. It seems to me that here is a great field for the geared engine. If the large, slow-speed vessel can be fitted with gearing, giving low revolutions adapted to a diameter of propeller limited only by the draught of the vessel, marked economies in power are certain to follow.

Rear Admiral C. W. Dyson, U. S. N. (Communicated):—I have been cognizant for quite a long time of the work being carried on by Commander McEntee along the lines as outlined by him in this paper, but have never heretofore had the opportunity offered me to scrutinize the results obtained by him except in one instance, that of the propeller designed by myself for the "Eagle" boats.

In this latter case the results obtained in the model tank agreed so closely with the estimates of performance as computed by the Bureau of Steam Engineering, and, from indications obtained on the trial of the first of these vessels, so closely with the actual performance as to instill into my mind a great confidence in the accuracy, and a supreme appreciation of the value, of model propeller experiments as now conducted by Commander McEntee.

Close Agreement of Model Experiments with Estimate of Performance.—Commander McEntee has requested me to analyze the propeller which he used in his experiments and to make an estimate of its performance behind the various hulls which he has used in order to ascertain the degree of agreement between the results obtained by the two methods.

In order to give a clear understanding it will be necessary for me to give a brief description of the method used by me and which has been obtained by many years' study of the performances of actual propellers driving actual ships over carefully measured courses.

The form of propeller blade selected from which to derive the design or performance factors is that of which the projected area is an oval with the greatest circular width at 0.7 the radius of the propeller from the center.

From these performances a series of basic curves of design has been obtained from which the performance of the propeller under these basic conditions can be obtained and the performance of the propeller under any other conditions of performance derived from this basic performance by the application of suitable factors entailed by the changed conditions.

The basic conditions are denoted as follows:—

I. H. P. = Basic indicated horse-power.
S.H.P. = I. H. P. $\times$ 0.92 = Basic shaft horse-power.
P. C. = Basic propulsive coefficient with maximum hull efficiency. (Taken for total projected area ratio.)
E.H.P. = I. H. P. $\times$ P. C. = Basic effective (tow-rope) horse-power.
P. A. $\div$ D. A. = Projected area ratio (outside 0.2 diameter) of 3-bladed basic propeller.
4/3 P. A. $\div$ D. A. = Projected area ratio of 4-bladed screw.
2/3 P. A. $\div$ D. A. = Projected area ratio of 2-bladed screw.
$1 - S = 1$ — Basic apparent slip (for 3 blades) and for fullness of after body of vessel.
I. T. D. = Basic indicated thrust in pounds per square inch of disc area of the propeller.

D = Diameter of propeller in feet.
P = Pitch of propeller in feet.
T. S. = Basic tip speed (3 blades) in feet, of propeller.
v = Actual speed of vessel.
e. h. p. = Effective (tow-rope) horse-power for v.

The power required to deliver e. h. p. where no cavitation exists is expressed by—

$$\text{I.H.P.}_d = \text{I.H.P.} \times K \div 10^z$$

where Z depends for its value upon the value $\frac{\text{e. h. p.}}{\text{E.H.P.}}$, and K is the thrust deduction factor.

The revolutions corresponding to the actual conditions of resistance are found by the following equations:—

$$s = \text{Apparent slip} = S \frac{\text{I.H.P.}_d \times A_V}{\text{I.H.P.} \times A_v}$$

where S is the basic apparent slip and A_V and A_v are factors depending upon the values of V and v.

It should be borne in mind that slight variations in the form of blade have only slight effect upon the efficiency so long as the same projected area is retained, but do have a considerable effect upon revolutions; therefore we should be prepared to find but small differences between the estimated and tank powers if both methods are correct, but considerable variation in the revolutions as the propeller used by Commander McEntee had blades of the Taylor form, while the standard blade form used by me, as already pointed out, is an oval.

In determining the block coefficient to use for basic apparent slip, the open water (where the propeller is not covered by the limits of the load water plane of the ship) correction is applied for Hulls 2132, 2133 and 2134, directly to the standard block as ordinarily obtained for hulls of the given length, beam and displacement; while for Hull 2135, which had abnormally full after body lines, this same correction has been applied to an increased standard block, this block being 0.80 in the first three cases and 0.85 in the latter, the corresponding open water blocks being 0.532 and 0.61.

The work of analysis and estimate follows, the estimated and tank powers and the estimated and tank revolutions being placed in parallel columns.

Hull Characteristics.

L.B.P. = 400′	Nom. B.C. = 0.7716	D ⩽ 0.7 H. ∴
B = 57.3′	B ÷ L.B.P. = 0.1433	Stand S.B.C. for V = 0.532
H = 26′	Stand. B.C. for K = 0.80	Stand S.B.C. for V
Displ. = 13137	Est. Stand. B.C. for	(Hull 2135) = 0.61
	K (Hull 2135) = 0.85	K = 1.27; for 2135 = 1.41

Basic Condition of Propeller.

P.A. ÷ D.A. (3 blades)	0.266
D	16.583′
P	14.75′
T.S.	5,900
$P \times R$	1,671

1—S (for S.B.C. 0.532)	0.89
(for S.B.C. 0.61)	0.90
V (for S.B.C. 0.532)	14.67
(for S.B.C. 0.61)	14.84
I.T.$_D$	3.1
I.H.P.	4,880
P.C.	0.695
E.H.P.	3,392
S.H.P.	4,490

ESTIMATE OF PERFORMANCE.

Hull	v	e. h. p.	e. h. p. / E. H. P.	Z	K	Shaft horse-power		Log A_V	Log A_v	S	Est. revs.	Tank revs.
						Est. power	Tank power					
2132	8	480	0.1415	.89	1.27	735	750	3.48	2.78	0.09	60.4	62
	10	1100	.3243	.51	1.27	1762	1800	3.48	3.01	.1274	78.7	80.5
	12	2580	.7607	.12	1.27	4325	4500	3.48	3.23	.1885	101.6	109
2135	8	610	.1799	.74	1.41	1153	1225	3.51	2.78	.1379	63.75	69
	10	1240	.3656	.455	1.41	2220	2250	3.51	3.01	.1564	81.44	86
	12	2500	.7371	.138	1.41	4607	4550	3.51	3.23	.1955	102.5	109
2133	8	450	.1327	.91	1.27	702	725	3.48	2.78	.086	60.8	61.5
	10	925	.2727	.588	1.27	1472	1480	3.48	3.01	.1065	76.9	77.5
	11	....	....	....	....	2030	2000	....	....	....	86.0	87
	12	1825	.5381	.276	1.27	3020	2850	3.48	3.23	.1316	94.9	98.5
2134	8	490	.1445	.855	1.27	796	850	3.48	2.78	.098	60.0	63
	10	1000	.2949	.553	1.27	1596	1700	3.48	3.01	.1154	77.66	79.5
	12	1825	.5381	.276	1.27	3020	3150	3.48	3.23	.1316	94.9	97.5
2023	8	480	.1415	.89	1.27	735	No data	3.48	2.78	.09	60.4	No data
	10	925	.2727	.588	1.27	1472		3.48	3.01	.1065	76.9	
	12	1660	.4895	.326	1.27	2679		3.48	3.23	.1167	93.3	

The agreement between the two power columns is so close that it appears to me Commander McEntee has developed a method for obtaining quickly and cheaply all such data as it has taken me years to collect and, from the data so obtained, not only to deduce absolutely correct factors for propeller design but also to so classify hulls along such definite lines that the performances of combined hull and propeller can be forecast with the minimum of error. He is most heartily to be congratulated upon the results of his labors up to the present time and I hope and trust that he has not yet reached the end of his investigations.

THE PRESIDENT:—Is there any further discussion on these two papers Nos. 9 and 10? If not, we will ask the authors to close.

PROFESSOR SADLER:—I would like to draw attention to the fact that Professor Yamamato, of the University of Tokio, had a good deal to do with the experiments here presented. I was called away before these experiments were quite completed, and I think our thanks are also due to him for the very careful way in which these experiments were conducted after I left the University of Michigan.

COMMANDER MCENTEE:—Referring to Admiral Taylor's remarks, no attempt was made to find the most efficient propeller for each model. There was time available to make

experiments with one propeller only, and that was chosen of the dimensions ordinarily found in practice with this type of vessel. Such propellers ordinarily make 85 to 90 revolutions per minute at a speed of 11 knots, the pitch ratio being about 0.9.

By reducing the revolutions per minute and increasing the diameter, the propulsive efficiency can be increased. I estimate that, with the same pitch ratio as used in the experiments, to increase the prismatic coefficient from 0.65 to 0.715—that is, by 10 per cent—it would be necessary to increase the diameter from 16.7 feet to 26 feet, and decrease the revolutions per minute at 11 knots from 86 to 44, with a corresponding decrease in slip from about 39 per cent to about 22 per cent.

As the full-load draught of the vessel is 26 feet, it is apparent that a diameter as large as 26 feet could hardly be used. If the largest diameter that it would be practicable to use is taken as 24 feet, the revolutions per minute would be 49, the slip 25 per cent, and the propulsive coefficient about 70. This would correspond to an increase of propulsive coefficient of something less than 8 per cent of the maximum found in the experiments.

There is another point about the matter which would require further experiment to determine, that is, as the propeller diameter is increased the propeller at the top of the disc would be working in water which has relatively a much greater wake, and it is probable that the hull efficiency would be somewhat less than that obtained with the smaller propeller.

In the foregoing discussion it has been assumed, of course, that there is no change in pitch ratio. It is possible that a reduction in pitch ratio and an increase in diameter might permit higher revolutions per minute without much sacrifice in efficiency.

With reference to the discussion by Admiral Dyson, it is extremely interesting. As is stated by him, his method of propeller analysis and design is based on data covering the performances of actual propellers driving actual ships over carefully measured courses. It is naturally gratifying to find that estimates of shaft horse-power as obtained by self-propulsion tests in the Model Basin agree so closely with estimates based on data obtained from the trials of actual ships. The two methods are entirely independent, so that the agreement between the results obtained by each naturally confirms the confidence in the reliability of the two methods. The agreement between the estimates made by Admiral Dyson and the results obtained in the Model Basin in the case of the best model—that is, No. 2133—which is nearest to the normal form, is remarkable.

The statement as to the reason for the difference between the revolutions obtained by the two methods is due to the standard forms of propeller blades used, particularly to the difference in thickness of the blades, the Taylor form used being considerably thinner than the Dyson standard; but even at that the variation in revolutions is not great.

Answering Mr. Robertson's query as to the apparent and true slip, these were both measured with reference to the pitch of the blade face, the apparent slip being the difference between the pitch speed of the propeller, that is, the pitch in feet multplied by the revolutions per minute, and the speed of the ship in feet per minute. The true slip is measured in a similar manner, but the speed of the ship is reduced by the amount of the wake.

The President:—I am quite sure that you will agree with me that a vote of thanks should be presented to each of these gentlemen, Professor Sadler and Commander McEntee. All those in favor of a vote of thanks to these gentlemen say "Aye"; contrary-minded, "No." It is unanimously carried.

Paper No. 11, "Recent Developments in Shipyard Plants," by Commander Sidney M. Henry, C. C., U. S. N., will now be read.

RECENT DEVELOPMENTS IN SHIPYARD PLANTS.

By Naval Constructor S. M. Henry, U. S. N., Member.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

Prior to the demand for naval and merchant ships, resulting from the needs of the present war, there had been for a number of years little development in the shipyard plants. It was hard to make both ends meet, and very little money was left for expansion, either in the amount of shipbuilding equipment or in its character. In the last three years these conditions have entirely changed, and sums of money beyond the dreams of a few years ago have been provided with the view of increasing the number of ships that could be built, and of allowing the more rapid and less expensive construction of the larger vessels.

Of that class of development, which consists in providing for a greater number of vessels, we have seen the principal examples in the fabricating yards at Hog Island, Newark Bay and Bristol, though the increase in number of ways available has been by no means limited to these yards. Many ways have been added in other yards, and entirely new plants have been built up.

The second general line of development has resulted in providing bigger and more modern building slips and larger and more effective shops, in order to permit the construction of the capital ships provided in the Navy's three-year building program, and to cut down the time of construction and save on the all-important item of labor. Development along these lines has not been required for the merchant program, and has, therefore, taken place only at the navy yards and at the plants of the older shipyards which have in the past been the builders of the Navy's armored vessels.

From a purely engineering point of view that form of development is likely to be the more interesting which provides for the building of the largest vessels, the handling of the greatest weights, and, therefore, the construction of the largest building ways and shops. Where the expansion of the shipbuilding facilities has been obtained by the creation of new yards of a few ways each, it would not be expected that any unusual plant developments would result. In the case of the great fabricating yards, there are, of course, many new problems, due to the vast size of the undertakings; but on the whole it is more a question of multiplying the slips and other facilities such as exist in yards with few slips than the creation of new designs of shops or new arrangements of slips and plants. The great increase in the number of slips in the newer fabricating yards, which is required by the number of vessels to be built and the short periods of construction contemplated, involves a multiplication of the number of men formerly employed in shipyards, of the weight

of material handled, of the provisions necessary for the receipt and unloading of cars, and of many of the other problems involved in the operation of the yards.

BUILDING AND REPAIRING.

So far the expansion of the shipyards of the country has been almost entirely in the direction of shipbuilding. After the vessels now being turned out in large numbers by the Emergency Fleet Corporation have been put in service, there will be a gradual shifting of the burden from the building to the repairing yards. It is perhaps well to look somewhat into the basis by which the capacities of both building and repairing yards can be considered.

So far as building is concerned, the natural unit is the building slip. A yard with so many slips should be able to turn out a definite number of vessels per year, depending on the length of time during which a vessel must remain on the ways. All other calculations are based on the number of slips provided and the estimated length of time that the vessels are to remain on the slips; that is, the extent of the shops, of the storehouses, of the fitting-out berths required, and the number of men that it is expected to employ; therefore provisions for housing and transportation are all a function of the number of slips and the length of time on the slips.

In passing from consideration of the building problem to the repair problem, this general method of viewing the question is lost, and some other basis of estimate must be adopted. The one which seems most nearly to meet the problem is the amount of berthing space, that is, the number of vessels that can be drawn into a yard at one time on which repairs can be carried out. Assuming a definite amount of berthing space, the maximum number of ships that can be under repair at a time is determined, and the extent of shops and the number of men for which provision must be made follows more or less automatically.

With a basis for arriving at the facilities required per building slip, and similarly per hundred feet or per thousand feet of berthing space, means are available for arriving at a reasonable judgment as to the total requirements for yards engaged on both new construction and repair work. Some of the more important elements of the shipyards, especially those involving greatly increased size or capacity, as compared to the earlier installations, will be briefly touched on.

BUILDING SLIPS.

The building slip itself, apart from weight handling facilities, has undergone comparatively little change. Concrete has been extensively used, but the majority of the new slips are of wood pile construction, and there is nothing unusual in their size except in the comparatively limited number of slips being provided for capital ship construction. These, in general, make provision for ships of a maximum length of 1,000 feet and beam of 110 feet, being the limiting size of vessels that can pass through the Panama Canal locks. So far as the beam is concerned, this does not represent a very radical increase over the largest battleships previously built, but

makes provision for a very great increase in the length as compared to vessels which have been so far constructed in this country, and involves the consideration of launching weights and facilities suitable for vessels of these great lengths. So far as the Navy Department designs are concerned, the capital slips have all been provided with an average inclination of slips of one-half inch per foot, provision being made for launching on a camber, the actual declivity of the building slips being seven-sixteenths inch per foot for the upper half and nine-sixteenths inch per foot for the lower half of the slip. The design of these slips contemplates the use of concrete throughout, though in a number of cases, due to lack of time or money, it has been necessary to substitute wood pile construction. With concrete slips of this great length, and the height that necessarily must be reached at the upper end of the slip, provision can be made for utilizing a very considerable area underneath the slip for stowage purposes and for carrying on such classes of work as can most advantageously be done in the immediate vicinity of the vessel under construction.

An interesting type of building slip, which perhaps is the first of its kind, at least on such a large scale, has been provided at one of our navy yards, where a shallow dry-dock has been constructed with a depth over the blocks at mean high water of 20 feet. The dock has essentially the same dimensions as the other capital slips, providing for a vessel slightly under 1,000 feet long and of a beam of 110 feet, and in the details of construction resembling other large dry-docks, except that the draught is very much reduced. The caisson will be of the usual type; provision will be made for pumping out the dock, but at a very much slower rate than would be needed if it were to be normally used as a dry-dock. With this arrangement, the weight handling facilities could be of any type that might be selected for the normal type of slip. In this particular case, the cranes are to be of the traveling, rotating, hammerhead type, with a capacity of 15 tons at 85 feet radius, electrically driven. The advantages which we look forward to in this construction are, first, of course, the elimination of the risk and expense of launching, and second, the facilitating of the erection, due to building on an even keel, and the elimination of the difficulties incident to delivering men and materials at the height of a vessel when built on an inclination. In addition to being on an even keel, the vessel will be very much lower, approximately 50 feet, and the height of the weight-handling cranes can be correspondingly reduced. If the conditions at the yard at the time make it desirable, the vessel can be carried to any degree of completion prior to launching, with the only limitation that the draught cannot exceed the depth of water over the blocks. The other side of the picture is the increased cost, which in this particular case, owing to the sub-soil conditions, not requiring piling, is not expected to be materially greater than in the case of the usual form of slip. For naval purposes, a building slip of this type has a further value, in that considerable periods of time may elapse during which building work is not carried out, and the slip will then be available for use as a dry-dock or a wet slip for small vessels.

CRANE SERVICE FOR BUILDING SLIPS.

There is perhaps more room for individual preference in the selection of the type of cranes to be used for handling material at the building slips than in any other feature of shipbuilding yards. This freedom of choice has been fully exercised in the extension of the older yards and the construction of the newer ones. With the exception of a limited number of special installations, such as the cableways used in some of the western yards, the available types fall into three general classes:—

1. Traveling, traversing cranes. Those which have both a longitudinal travel and a cross travel.

2. Traveling, rotating cranes. Those which have a longitudinal travel and a rotating motion.

3. Fixed, rotating cranes. Those which have no longitudinal travel, and deliver their material at the desired point by rotating, and either by trolleying or luffing.

In the first class is included the cantilever type, which was in favor in the early days of large shipbuilding, but which has now generally been abandoned, at least as far as new installations are concerned; and the bridge type, which probably gives the most effective service, though generally at the highest cost. Cantilever cranes are not a desirable type on account of the great inertia of the moving part, and on account of the limited number of hooks that can be made available, the combination tending to limit the speed of erection. Bridge cranes permit the handling of the heaviest weights and provide an installation that most nearly approximates shop conditions, so far as concerns ability to deliver material at all points. The principal argument against this type is its initial cost. It has been generally adopted for the larger and more expensive slips, and some one of the rotating types has found most favor for the slips intended for smaller vessels, or where it is not feasible to finance the higher original cost.

The traveling rotating types include the hammerhead and luffing types of cranes operating on wide-gauge tracks on the ground, and also electric and steam locomotive cranes operating on runways of the general type used with cantilever cranes. The cost of these types is apt to be less than bridge cranes and also less than the fixed, rotating cranes, if a limited service only is to be provided. With an equivalent service as compared with the fixed, rotating cranes, the cost should not be radically different. Some very rapid construction in the last few years has been done, utilizing electric locomotive cranes on elevated runways, and where the weights to be handled are not high or the length of the ships under construction great, this gives an effective service. The cranes that travel on the ground are more expensive than is at first apparent, on account of the cost of the track installation. Their longitudinal travel is relatively slow, owing to the inertia of the moving parts. In general, this class of crane appears to the best advantage in building vessels of moderate size, where the individual weights to be handled are not large.

The fixed and rotating cranes involve a great variety of types, which include the hammerhead type, the luffing boom type, both rotating on relatively high towers, the staid type supported on the ground, and derricks placed on towers such as are in general use in building construction. In general, the most suitable field for this class of crane is the slip for smaller ships, involving the handling of small weights, as the handling of relatively heavy weights means the providing of a large capacity for most or all of the cranes. The chief objection to them lies in their relatively small capacity and short reach, necessity for large numbers of operators, and the difficulty in delivering and storing material within reach of the crane to be used in placing it on board the vessel. There have been some recent installations in the navy yards of the revolving, hammerhead type of cranes, which for small vessels have proved to be very satisfactory. These have a capacity of 5 tons at 95-foot radius and 10 tons at 50-foot radius, the height of hook being about 95 feet above the ground. The new capital slips being built in the navy yards are all of the bridge crane type with characteristics adopted after many tentative designs which considered capacities from 10 tons to 150 tons. The arrangement as finally adopted provides for two 40-ton cranes, each spanning the entire structure, and permitting a lift of 80 tons, with a double row of cranes above the main cranes, all of them plumbing the center line, and having capacities of 10 tons each.

In these slips provision has been made for the construction of a maximum vessel of 110-foot beam, or for two merchant vessels abreast or three destroyers abreast. The clear width between the columns of the crane runways is 130 feet, and the columns slope outward so that the hooks of the cranes will plumb the centers of cars on the standard gauge tracks running the length of the slip under the towers on each side. This requires a crane span of 151 feet 9½ inches. The height of the hooks of the main cranes above the yard level approximates 125 feet. The center to center width of these slips is 164 feet, and as they provide for the construction of ships with 110-foot beam, the ratio of slip to vessel is 1.49. This is a dimension that has a direct bearing on the selection of the type of crane to be used. The ratio of the distance between centers of slip to the beam of vessel becomes in large yards a feature of considerable importance as regulating the total amount of water front required for a given number of ways, and to a certain extent the area of land to be included in the plant. As many factors of cost of plant bear a direct relation to the area, any unnecessary extension involves an undesirable increase in cost.

STRUCTURAL SHOP.

The activities of the yard most directly connected with the building of ships are housed in the structural or shipfitters' shop. There has been, in the development of the larger private yards and of the principal navy yards, a tendency to adopt common characteristics, with the result that some of the largest private and government plants have adopted almost identical characteristics, though arrived at independently. In several instances the navy yards are erecting a structural group which in-

cludes not only the shipfitters' shop, but also the forge shop and boiler shop, and may later include the sheet metal and pipe shops. The shipfitters' shop in each of these cases consists of two bays, one for plate work and one for angle work, each 100 feet wide and 700 feet long, a mould loft being provided over the angle bay of the full size of that shop. The under side of the floor of the mould loft and of the roof trusses of the plate shop is at a height of 45 feet above the shop level, and the height of mould loft from floor to roof trusses is 9 feet. The plate and angle shops are provided with three tiers of cranes, the upper tier spanning the full width of each bay, having 15 tons capacity, and providing for a total lift of 30 tons; the second tier consisting of traveling jib cranes of 3 and 5 tons capacity at reaches of 30 and 20 feet with a hook height of 25 feet. The lower tier consists of special cranes intended to carry yoke riveters and smaller portable tools. For these last cranes electric motors for travel are provided with a swinging boom and a chain hoist to facilitate the handling of such tools. The lower tier of cranes will extend for about a third of the length of the shop at the outgoing end, as they are intended primarily for work in connection with assembling and riveting.

Structural material is to be stowed on the principle followed by many of the bridge builders, a series of bridge cranes operating on runways extending across the incoming end of the shop. This stowage space will provide an area of approximately 160,000 square feet, consisting of four bays served by bridge cranes with 80-foot spans, and the area will eventually be roofed over. It is proposed to deliver material into the stowage space by standard gauge tracks, and to deliver into the bays of the shop by narrow gauge tracks. It is not expected that 160,000 square feet will give the full stowage area required for building and repair work for the largest yards, and further provision will be made for a reserve stowage in a less central location. Continuous flow of work is to be obtained by the raw material entering at the end of the shop adjacent to the stowage yard going first to the laying-off space, then to the fabricating area and thence to the assembly space and out at the opposite end of the shop, delivery from the shop to the building slips being by means of standard gauge tracks. With this arrangement, a piece of material may be delivered from any point in the shop to any ship under construction with a maximum of three moves, the first from its position in the shop to a car by means of a bridge crane, the second by the transfer of the car under the slip, and third, from the car to the location desired on the ship by a bridge crane. There is no combination of shop bays and building slips, where there is more than one of each, that can accomplish this transfer with less than three moves.

The size of plates used in ship construction has grown steadily, and an effort has been made in laying out these shops to adopt as the maximum size that we are likely to come to, a plate 36 feet long by 8 feet wide, and to provide machine tools and arrangements so that any increase in size up to this point may be taken care of without the discarding of the present outfit or its rearrangement. In comparatively recent years we have gone successively through the stages of equipping for 24-foot, 28-foot, 30-foot and 36-foot plates. The cost of equipment, especially rolls, increases

rapidly at the very long lengths, and machine-tool manufacturers are not generally equipped to provide machines of greater capacities, so it is likely that an increase beyond this size will not come for some time.

FITTING-OUT CRANE.

The nature of the building slips has been touched on, also the characteristics of the structural shop, and the next item which plays an important rôle in the general scheme of construction is the fitting-out crane; for on its size and ability to handle heavy weights is dependent to a considerable extent the point at which it is desirable to launch and the condition of assembly of machinery and other parts that can be taken care of.

Compared with the large shipbuilding plants abroad, there is poor equipment for handling heavy weights in this country, whether in private yards or in government establishments. The maximum capacity of any crane in this country at the present time, so far as shipyards are concerned, is 150 tons, and there are few of these, whereas in the big foreign yards there are many cranes of 250 tons capacity. The great cost of this class of equipment has undoubtedly prevented its installation, especially in view of the fact that very large merchant construction has not been undertaken, and it has been possible to get through past naval programs with available facilities. With the possibilities of larger merchant construction and the growth in the size of naval vessels and of their ordnance, 150-ton cranes are no longer of sufficient capacity, and provision for a materially larger lifting capacity must be made if future naval requirements are to be met.

The heaviest weights required in ship construction are the turrets of battleships. Their weight, stripped of armor and guns, is likely to be in excess of any practicable crane, so that the problem to be faced in determining crane capacity is how great a capacity can be obtained without involving excessive or unreasonable expenditures. All of the Navy's large cranes have so far been of the floating type, the earlier ones of the cantilever construction, and the later of the revolving, luffing type.

An investigation of the possibilities of building floating cranes of materially greater capacity led to the opinion that the cost of such cranes would become prohibitive, and further, that their great size would be such as to make it practically as difficult to move them as to move the ship for which the weights are to be handled. This study further led to the view that it was feasible to obtain fixed shore cranes of the revolving, hammerhead type of 350 tons capacity, but that a capacity approaching this could not well be obtained with a traveling crane of any type, and that no other type appeared to compare favorably with the hammerhead type. As a result of this investigation a crane is now under construction for one of our navy yards having a capacity of main hoist of 350 tons at a radius of 115 feet, and of 50 tons at a radius of 190 feet. In addition to the main hoist, there is an auxiliary hoist of 50 tons capacity. The height of the main hoist above the yard level is 145 feet. The base of the crane is of the portal type, the over-all width being 61 feet,

with a clear opening of 51 feet, allowing for a double track, standard gauge system running through it. It is proposed to install the crane on the center line of a pier of 100 feet width, giving a clear reach of 65 feet at 350 tons capacity, and 140 feet at 50 tons capacity. The crane will be installed 400 feet from the outer end of the pier 1,000 feet long, the location being based on allowing the handling of weights on any point of a vessel 1,000 feet long, and for giving the most convenient handling of weights for vessels of lesser lengths. So far as we know, this will be the largest crane that has yet been built for the shipbuilding industry. Located as outlined, the crane will give equal service on both sides of the pier, and can take the heaviest loads from barges on one side and place them on board vessels secured on the other side.

TURRET SHOP.

One of the serious problems connected with the building of large naval vessels is the completion and installation of the turrets within the period of construction of the vessel. With comparatively limited weight handling facilities, the construction of the turret cannot proceed beyond the assembly of the bare structural work until after the vessel is launched, the heavy structure being handled in separate pieces to be assembled on board the vessel. The large amount of fitting and installing then remaining occupies the entire time until the vessel is completed. A method of construction which offers much brighter prospects for rapidity, but involves large initial expenditures for equipment, is to build the turrets complete in a shop, to then remove the armor and guns and strip the turrets to a weight that can be handled by the fitting-out crane, and to lift the turrets on board in this condition soon after launching. With a crane of the capacity described above, this process is entirely feasible, but involves the provision of a turret shop. The work to be done in such a shop is a combination of work such as is done in the structural shop and in the machine shop, and involves very heavy crane service and great height of building. In order to get the maximum benefit of the fitting-out crane, the capacities of the shop cranes should be equal to it, and designs have been prepared for a shop of this type which is to have a height to the under side of roof trusses of 94 feet and span of 100 feet, and to be fitted with two 150-ton bridge cranes, giving a combined capacity of 300 tons. With a shop of this character located on the water front, it will be feasible to extend the crane runway over the water a sufficient distance to permit the placing of a turret on a barge, which in turn will deliver it within reach of the fitting-out crane.

Owing to the great height of the completed turret structure, it is necessary either to provide a deep pit for the lower portion of the turret to extend into, or to provide an excessively high roof; or, what appears better, to combine the two methods, which can be done, with a height of 94 feet to the roof trusses and depth of pit of about 16 feet. These dimensions are sufficient to allow the complete assembly of a number of turrets and their removal from the shop as completed. A length of shop of about 60 feet per turret will be required.

Plant developments, such as are described above, are justified only where large construction work is to be carried out. In turn, such construction necessitates the production of large steel forgings and castings and their machining ready for installation. Few of the private yards have been in a position to make their largest iron castings, and practically none to make their steel castings and forgings. The present development of these shops in the navy yards is intended to place them in a position that will enable them to make promptly any repairs that may be needed in war time, with the single exception of heavy ordnance.

FORGE SHOP.

In order to make the largest engine and hull forgings, an equipment consisting of a 2,000-ton high-speed steam hydraulic forging press and smaller presses and hammers is required, as well as furnaces and heat treating equipment necessary in connection with the operation of presses of this size. A building consisting of a main bay 65 feet wide and 67 feet to the under side of roof trusses has been provided for the heavy forging work with two 80-ton cranes. In addition to the main bay, there is being provided a lower bay with 5-ton crane service, and with a height of 29 feet, to take care of the hand fires, etc. In view of the character of the work done in the boiler shop and the size of the crane equipment required for it, it has been considered desirable to combine these two shops in one, for this purpose providing a total length of 700 feet. An effort has been made in laying out these shops to get away from the old idea that a blacksmith or forge shop must necessarily be dirty and poorly lighted without the usual conveniences found in other shops. The type of construction is the same as adopted for the other large shops, that is, steel frame, hollow tile and steel sash sides and Aiken roof. It is intended to provide a wood block floor, except in certain locations of limited area where hot metal is likely to come in contact with it, in which locations cast plates will be fitted. With a clean floor, ample light and ventilation and oil fuel, it is expected that the working conditions can be made in this shop to approach those found in other yard shops.

FOUNDRY.

Provision will be made in the new foundries for the production of all sizes and characters of castings used aboard vessels. The buildings are to have a main bay 80 feet wide and 75 feet to roof trusses with about 80-ton and 15-ton cranes, as well as traveling wall cranes. The side bays are to be 55 and 45 feet wide, the one on the side opposite the cupolas to have a second floor. There will be provision for brass, iron and steel casting, the equipment including both electric and open hearth furnaces, able to make the largest steel castings called for by naval vessels.

MACHINE SHOP.

Provision in the machine shops must be made, not only for handling the forgings and castings of the largest size, for which some of the yards are already pro-

vided, but also to take care of a much larger volume of work than has been provided for in the past. The larger machine shops now under construction meet the general development under way in the other departments and consist of a main bay, 80 feet wide, with a height of 85 feet to the roof trusses; with a secondary bay, 50 feet wide, with a height of 26 feet to the cranes of 20 tons capacity; and a second floor of the same width, crane capacity of 5 tons, and a height of 18 feet to crane rail. Lean-tos outside of this take care of offices, tool rooms, locker rooms, etc. It is expected that a total length of shop of this section of approximately 1,000 feet will take care of all of the large work. In addition, a machine shop for small work will be provided of the same length with a width of approximately 60 feet, and six stories in height.

The outline in the case of the last three shops is very brief and is intended only to give a general idea of the expansion and development found necessary and being made in these departments to conform to the developments under way in the departments that build the hulls.

The growth of many of the minor activities has not been out of proportion to that which we find in the main elements of the yards, and such activities as galvanizing and generation of oxygen, which have in the past been placed anywhere that room could be found for them, have grown to the dignity of independent shops of considerable size, and other activities are still coming on, which give promise of taking a prominent place in shipyard work, the most outstanding of these at the present time being electric welding.

We have to thank the present demand for ships for the progress that has been found possible in the development of the plants. With a continued demand for more and larger ships, it is to be expected that the growth of the plants, which has been begun, will be rounded out so that each department will in its own line be able to compare favorably with the best shops doing a similar character of work in other industries.

DISCUSSION.

The President:—The next paper which we will take up is No. 12, entitled, "Present Status of the Concrete Ship," by Mr. R. J. Wig, Visitor.

Mr. Wig presented the paper, and in connection therewith made the following statement:—

"Up to two or three years ago the majority of engineers were rather skeptical about the possibility of building concrete ships, but to-day it would be difficult to find a structural engineer, familiar with reinforced concrete, who does not believe that concrete ships can be built structurally the equal of a steel ship. Many of you gentlemen are steel shipbuilders and may question this statement. The only feature of the concrete ship which may limit its life to this emergency is that of economic operation. Whether we can build it light enough so that it can be operated and compete with other forms of construction has not been determined."

PRESENT STATUS OF THE CONCRETE SHIP.

By R. J. Wig, Esq., Visitor.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

There is much interest throughout the world in the development of the concrete ship. Ships of concrete are at the present time being built in England, France, Spain, Italy, Germany, Norway, Turkey, China and the United States, but so far as we are informed, there are no concrete ships under construction outside of the United States larger than 3,000 tons deadweight. The United States Government now has under contract 56 concrete ships, varying in size from a few hundred tons to 7,500 tons deadweight, aggregating 300,000 tons total deadweight, in addition to some 34 barges and lighters, and the future position of the concrete ship should be established by the results obtained from these ships which are now under contract and building.

The use of reinforced concrete for ship construction has been suggested by the structural engineer and not by the naval architect. Like all innovations its development has been observed by some with much skepticism. The structural engineer has worked under a great handicap in not knowing the premises of ship design, and during these very busy days of the past two years it has been difficult to obtain the assistance of naval architects who could join the structural engineer in adopting this new material to ship structures.

It is a misnomer to call the concrete ship a "stone" ship. It is essentially a steel ship in which the proper quantities of steel are located where strength is necessary and concrete is used as an envelope and cementing medium with certain contributing strength.

Unfortunately the structural design of ships in general has not been developed on theoretical grounds, but rather from empirical standards and experience. Reinforced concrete is such a radically different material from steel and has such dissimilar physical properties that it has been necessary to devote much time to theoretical analysis of the ship structures which is not undertaken at all in steel ship design.

Reinforced concrete is a structural material which is capable of carrying any structural strains which can be carried by steel alone; therefore, in order to make a concrete ship equal structurally to a steel ship, it is but necessary to make careful analysis of the steel ship both as a whole and in its individual elements, to provide the required quantities of steel as reinforcement in the concrete where tensile strains are involved, and provide the concrete to care for the compression and shear strains

and as a carrying envelope for the steel. When reinforced concrete was first proposed for building construction, only a few years ago, its use was prohibited by many of our municipalities, and engineers looked upon the innovation with skepticism. Today the structural steel building is the exception, and reinforced concrete is accepted as one of our most reliable structural building materials.

The first reinforced concrete cargo motor ship was designed and built by the Fougner Concrete Shipbuilding Company at Christiania, Norway. It was of 400 tons deadweight and was launched in August, 1917. This ship has been in constant service for over one year, and a recent report states that it is giving thoroughly satisfactory service and shows no cracks or defects of any kind.

The concrete ship Faith, which is the pioneer American concrete ship, is of 5,000 tons deadweight. She was successfully launched in March, 1918, made her maiden voyage from San Francisco to Vancouver and return, passing through a severe storm without showing structural weakness of any kind. She has since sailed with cargo to Peru and has made a return voyage from Iquique, Chile, to New Orleans, via the Panama Canal, with a cargo of nitrate. She now is bound for New York via Cuba with a cargo of sugar.

This ship has received the normal treatment of all ocean-going ships, having sailed under her own steam, been towed, docked and dry-docked without evidence of weakness. She will enter the transatlantic service upon completion of the present voyage. The ship and cargo are both insured at rates only very slightly higher than those charged for steel ships of the highest classification.

The concrete ship is truly a product of necessity. We have been working on the concrete ship comparatively a very short time and therefore we do not expect the present ships to be the ultimate concrete ship; they must be judged as pioneers, and imperfections are to be expected. Since the concrete ship of large size (3,000 tons and over) is being developed almost wholly in the United States, and mainly by the Emergency Fleet Corporation, a discussion of the present status of the concrete ship will be confined largely to a discussion of this work.

In the development of the designs prepared by the Emergency Fleet Corporation, experienced naval architects and structural engineers have been employed. J. L. Bates and F. B. Webster have furnished the lines for these ships and have been responsible for the necessary scientific ship studies. The concrete ship differs considerably in weight distribution from other types of ships, and the structural material is of such a nature that the concrete ship must receive special consideration and study not ordinarily required in other ship design, in order to obtain the most economical distribution of material for the required strength, both from the standpoint of weight and of construction. The girder strength is determined by the conventional methods ordinarily used in steel ship design. The exact method employed is fully described in a paper presented at Atlantic City at the meeting of the American Concrete Institute in June, 1918.* In addition to these normal calculations very careful studies have

*"Problems Arising in the Design and Construction of Reinforced Concrete Ships," by R. J. Wig and S. C. Hollister. American Concrete Institute, June, 1918.

been made of the transverse strength. This is not commonly done in steel ship design, for the size of the transverse frames is fixed by the classification societies, being based upon data accumulated from many years' experience. The methods employed in our calculations are fully described in the paper referred to above and will not be repeated here.

Specialists have been employed to develop the various elements of the structural design. In reinforced concrete design it is essential that we know the distribution, character and magnitude of the strains throughout a structure in order to properly locate and proportion the steel reinforcement.

There has been considerable discussion relative to the combined torsion and shear strains in a ship. A very thorough analytical investigation of this subject has been made by H. M. Westergaard, one of our engineers. The results of these studies will, no doubt, interest you and they are given below:—

Torsional stresses are produced when the ship passes over the waves making an acute angle with the waves. In order to find what increase of stresses can be expected due to this effect, an analysis was made of the torsional moments and the stresses produced by them. To find approximately the wave condition giving the maximum effect, a rectangular water-line section was first assumed, width one-eighth of the length. The usual assumption was made that the hydrostatic water pressure varies directly with the depth under the wave surface. For the sake of simplicity a sine wave was assumed instead of a trochoid, correction for the difference being made afterwards. As usual the wave height was taken one-twentieth the length. The maximum torsion midship was then found to occur when the wave crest makes an angle of 19 degrees with the ship, when the line of the wave crest passes through the center of the ship and when the length of the wave is 0.475 times the length of the rectangular water-line section. Using the notation—

T = total torsional moment.
I = moment of inertia of water-line section.

the maximum static torsion midship was found to be expressed by the formula:—

$$T = 3.20 \text{ lb.-feet}^3 \times I$$

(I measured in feet^4 gives T in lb.-feet.)

This formula must now be revised from three viewpoints. First, the wave is a trochoidal wave, not a sine wave. Second, the water-line section is a ship-shape section, not a rectangle. Third, the dynamic action should be considered. Assuming the wave length and angle as indicated above, the first two causes for revision appear to have equal and opposite effect, the trochoidal wave shape increasing the effect by 6.5 per cent beyond what is found for the sine wave, while the ship-shape water-line has a similar decreasing influence on the constant in formula (1) (the 28′ water-line, design 41, was used in the comparative computation). The third cause for revision, the dynamic action during rolling, appears not to change the value of the maximum torsion midship, provided the mass is fairly uniformly distributed.

Under this assumption the increase of the torsion due to dynamic action appears to be such that the resulting lengthwise diagram for the maximum torsional moments is a parabola, the maximum ordinate of which is given by formula (1). The torsion is maximum at or near the center, zero at the ends. It is emphasized that I in (1) is the transverse moment of inertia of the actual water-line section.

When the total torsional moments in the various sections have been found, the next step is to determine the internal distribution of stresses caused by the torsional moment in each section. As in the case of a shaft, the torsion stresses are essentially shears in transverse and longitudinal sections, though longitudinal tensions and compressions may occur locally, say, where the section changes. Longitudinal tensions and compressions would also occur in the abnormal case of a deckless ship, in which the torsional resistance would consist of a resistance against bending of each side of the ship, the one side upwards and the other side downwards. In order that the torsional stresses shall not be large, it is essential that one or more shells are formed by sides, bottom and deck, or by sides, bottom, decks and longitudinal bulkheads. These cases may be considered the normal ones, and these are the cases in which the essential effect is shears in the transverse and longitudinal sections. These shears can be evaluated by analysis, either by the principle of consistent deformations or by the principle of least work. If only a single shell resists torsion the stress may be expressed by a simple formula which will be given. The notation is:—

A = area enclosed by the center line of the cross-section of the shell (for instance, cross-sectional area of the ship).

T = total torsional moment.

S = shear per unit length of circumference of shell.

The formula is then—

$$S = T/2A$$

(A measured in square feet, T in lb.-feet gives S in lb.-feet.) S is a constant all through the circumference. One central longitudinal bulkhead would not change the conditions, as, on account of the symmetry, it would not itself carry any torsional stress. Two longitudinal bulkheads would release the sides of, say 8 per cent of the torsional stress (typical case), but would increase the stress in the central parts of bottom and deck by about the same amount.

Finally, the torsional shears should be combined with the shears of the regular vertical shear action. The regular vertical shear and the torsional shear do not become maximum for the same wave condition, hence the combination of the two effects cannot consist of a simple addition. We assume the conditions to be such that a 30° angle between wave crest and ship gives maximum torsional stress (this assumption is on the safe side, as slightly lower resulting values are found when the angle is smaller). Further, it is assumed that the wave section in the direction of the ship has top and trough at the same points for maximum regular shear and maximum torsional shear. This assumption is also on the safe side. It is then found that the following formulas for the combined effect give very close approximations. The notation is:—

s = maximum unit shear due to regular vertical shear action.
t = maximum unit torsional shear.
s^1 = maximum combined unit shear occurring at some intermediate wave condition.

The formulas are:—

$$s^1 = \sqrt{s^2 \quad 1.5 \quad t^2} \qquad \text{for } t < s \tag{3a}$$

$$s^1 = \quad t \quad .6 \quad s \qquad \text{for } s > t \tag{3b}$$

a typical condition is represented by $s = 400$ lb./sq. in., $t = 80$ lb./sq. in. Formula (3a) gives in this case for the combined shear

$$s = \sqrt{400^2 \quad 1.5 \quad 80^2} = s\ 412 \text{ lb./in.}^2$$

As conclusions may be stated:—The torsional stresses are not negligible by themselves. In arranging the cross-section of the ship it should be held in mind that these stresses exist and that they are resisted most effectively by complete closed shells, formed by deck, sides, and bottom, or by decks, sides, bottom, and longitudinal bulkheads. At points where the section changes—for instance, at the ends of hatch openings—the local stresses due to torsion may reach high values unless special reinforcement is provided and unless the details are carefully worked out. However, when the design is such that the torsional stresses in the shell are kept reasonably small, say not more than one-quarter or one-third of the maximum shear due to the regular vertical shear action, then the increase of the combined shear beyond the value of the regular shear is very small and can be considered as negligible.

In addition to the analytical studies it has been necessary to obtain data on the physical properties of structures of unique design and concrete mixtures which had seldom before been used in structural work. These structural investigations are made under the direction of W. A. Slater at the Bureau of Standards' laboratories at Washington and Pittsburgh, the laboratory of Lehigh University at Bethlehem, Pa., and the Office of Public Roads, Arlington, Va.

The investigations are made to establish safe working stresses and standards of design. Tests already made demonstrate the safety of the designs first made and indicate how weights may be further reduced without sacrificing strength.

One of the first serious difficulties in the design of concrete ships was that of getting sufficient strength to prevent cracks forming diagonally in the vertical sides of a ship of practicable weight. Using the methods ordinarily employed in reinforced concrete design, a shell thickness of at least 15 inches would have been required instead of the 4 inches used in our 3,500-ton cargo ship.

Tests of large reinforced concrete beams were started to make certain that no mistake was being made in using a 4-inch shell. These first tests were made on:—(*a*) Beams 4 feet 4 inches deep and 18 feet 6 inches long; (*b*) one beam 10 feet deep and 22 feet long; and (*c*) specimen ship frames of full-size cross-section and 20 feet span. The frames were cut off at a point corresponding to the point of inflection or 4 feet 6 inches above the top of the keel. The tests were made in the 10,000,000-pound testing machine at the Bureau of Standards, Pittsburgh.

For the beams the load was applied at the center of the span upon the upper flange. The beams were supported at each end on a steel plate girder. The beam 10 feet deep was first loaded forty times with 640,000 pounds, which was four times as much as the maximum which the Standards of the Joint Committee on Concrete and Reinforced Concrete would have allowed as its working load. The widest crack at the first application of this load was thirteen one-thousandths inch, and with forty repetitions of the load there was no appreciable increase in widths of cracks. The beam was then inverted and load was applied in the opposite direction, causing failure at 1,363,000 pounds or nine times as much as the Joint Committee standards for reinforced concrete design would have allowed as a working load.

Plate 104 shows this beam after it had been loaded from one direction. The cracks were painted to make them visible. The holes and channels cut in the concrete exposed the reinforcement to allow measurements of change of length of the bars to be made. Plate 105 shows the beam after completion of the test in an inverted position. The cracks formed in this test were approximately at right angles to those due to the first test. This view also shows the manner of failure.

The ship frames were tested by applying, first, only a vertical load and adding later a horizontal load at the sides corresponding to the horizontal water pressure on the sides of the ship. It was found that the strength here was about eight times as great as the Joint Committee recommendations allowed for the working load, also that the shear due to the horizontal forces reduced the stresses set up by the shear due to the vertical forces; in other words, that the horizontal water pressure would reduce the stresses caused by the vertical shearing forces on the frame. The form and size of the ship frame specimens are indicated in Plate 106, which was taken before any load had been applied. Figs. 1 and 2, Plate 107, show opposite sides of the same frame after failure. The cracking was about the same on both sides, but in Fig. 2 the cracks had been painted to make them visible. This view shows also the places where the reinforcing bars were uncovered for the purpose of measuring elongations and shortening during testing.

A larger series of beam tests is being conducted at Lehigh University. Plate 108, shows the reinforcement for a typical beam of this series. Plate 109 shows a beam in the testing machine. These tests confirm conclusions based on the Pittsburgh tests and will afford much more complete information on which to base design.

These tests have made it possible to design with confidence, using working shearing stresses much higher than those which are recognized by the Joint Committee on Reinforced Concrete for structural members of ordinary design and proportions. However, it has not been necessary as yet to use working stresses as high as appear from the tests to be justified.

Tests are under way to determine the effect of rapidly repeated loads on a reinforced concrete beam. A beam supported in a frame has a motor operating a lever in such a way as to apply a known load to the beam alternately upward and down-

ward at the rate of about 36 load applications (18 complete cycles) per minute. The tensile stress developed in the steel is about 23,000 pounds per square inch, and 746,000 applications of the load had been made up to August 18, 1918. There had been no perceptible increase in the strain in the steel or the concrete after 1,000 applications of load and very little increase between the first and the thousandth application. Cracks appear in the lower portion of the beam under downward load and in the upper portion under upward load. The largest cracks on August 18 were about 1/100 inch wide. With continual opening and closing of cracks, if any should occur in the alternate hogging and sagging of a ship, the possibility of a grinding action on the fractured surface has been considered as a possible destructive agency, but thus far in the test no such grinding has been observed.

During the making of all large test specimens, small specimens of concrete have been made, using the same material as that going into the large specimen. The compression tests of the small specimens show strengths as great as the assumed strength on which the working stresses used in design were based.

In order to determine whether in the complicated network of reinforcement present in the ship structure the quality of the concrete could be made satisfactory, special tests were made. Slabs 4 inches thick, with a very large amount of reinforcement made up into a complicated network, were poured on edge to a depth of 3 feet. All parts of the structure were well filled out with concrete, covering all the reinforcement satisfactorily, and, in the load test which was applied, failure occurred by tension in the steel before reaching the ultimate strength of the concrete, although a stress of about 4,400 pounds per square inch in compression in the concrete had been developed.

All the evidence thus far accumulated indicates that a concrete strong enough to warrant the use of a high working stress in compression (1,500 pounds per square inch) can be obtained in all cases where sufficient attention is given to the placing of the concrete.

Tests are under way to determine the conditions under which leakage through construction joints and through cracks may be expected, and how it may be prevented. Thus far hollow beams, having wall thicknesses of 4 inches and construction joints in which as much as seven hours elapsed between the pouring of successive layers of concrete, have been tested under a 30-foot head of water. No leakage occurred through any of the construction joints and apparently none through the side wall except where the wall was penetrated by a steel tie bar. However, leakage did occur through the thicker upper flange of the beam where imperfections in the construction occurred.

While under a pressure due to a 30-foot head of water, the beams were loaded so as to give a shearing stress of 300 pounds per square inch. It was found that where a diagonal tension crack was as much as 0.002 inch wide, a small amount of leakage occurred, and where it was 0.004 inch wide the leakage was appreciable. The tests are being continued to obtain more complete results.

An inspection made by the United States Bureau of Standards in 1917 of rein-

forced concrete oil tanks then in service indicated that mineral oils had no deleterious effects on concrete which was cured before contact with the oil. The series of tests now under way confirms this conclusion and shows that certain organic oils do have a destructive effect on the concrete used.

The penetration tests are being made with oil under a maximum head of 16 feet. The penetration into 1-2-4 concrete for the lightest oil used (73.7 Baume) was about 1.6 inch in 40 days, and for the heaviest oil (95.5 Baume) it was about 0.27 inch. Preparations are being made for tests under a head of about 25 feet.

Tests are under preparation to determine the relative advantages, for taking stress, of placing slab reinforcement parallel to and at an angle with the direction of the span. No results for these tests are available as yet.

In a beam having large variation in the area of the cross-section there is uncertainty as to how much of this area is fully effective in resisting the tensile and compressive stresses. Analysis indicates that, if the entire area is available, the use of properly designed haunches in ship frames may permit a reduction in the weight of ship frames of from 20 to 30 per cent of the weight required on the basis of existing standards. A series of tests to obtain information on this question is now under way, but no results are yet available.

The unit stresses now employed in the structural design are as follows:—

CONCRETE.

1. Maximum unit compressive stress in the extreme fiber in flexure ..... 1,500 lbs. per sq. in.
2. Maximum unit compressive stress in the extreme fiber in flexure, adjacent to support of a continuous or fixed ended beam ..... 1,700 lbs. per sq. in.
3. Maximum unit compressive stress in stanchions ..... 1,000 lbs. per sq. in.
4. Maximum unit shearing stress $\frac{V}{bjd}$ in tee beams and in shell or other slabs ..... 500 lbs. per sq. in.
   In isolated beams ..... 300 lbs. per sq. in.
5. When the maximum unit shearing stress is less than 50 lbs. per sq. in., the concrete may be considered to carry all the shear.
6. When the unit shearing stress is greater than 50 lbs. per sq. in, reinforcement should be provided as follows:—

(*a*) In the design of thin slabs, used as the webs of beams, with the shearing action perpendicular to any local shearing stress such as the shell, provide shear reinforcement according to the formula and the diagram prepared by W. A. Slater, and a formula for combining shear and local stresses.

(*b*) In all other cases provide shear reinforcement to carry the full amount of the shear.

7. Maximum unit bond stress not over..... 160 lbs. per sq. in.
or steel stresses to 16,000 lbs. and proportionally for other steel stresses.

8. $n - \frac{Es}{Es} = 10$

STEEL.

1. Maximum unit tensile stress in all reinforcement except as stated below, not to exceed.....16,000 lbs. per sq. in.
(*a*) In *all bulkheads* except collision bulkheads .....20,000 lbs. per sq. in.
(*b*) In shell reinforcement exposed to water.....12,000 lbs. per sq. in.
(*c*) Maximum unit tensile stress in top steel of keelsons due to combined local and hogging or sagging stresses not to exceed .....20,000 lbs. per sq. in.

Aside from the design problems, much work has been done in developing materials which would have greater structural strength than ordinary concrete, and less weight. If the concrete ship is to become a permanent institution, it is necessary that the unit weight of the concrete be reduced. Our efforts in this direction have been very satisfying. We have developed an aggregate of bloated clay which floats on water. Concrete made of it weighs less than 110 pounds per cubic foot, which is 20 per cent less than that obtained from normal sand and gravel aggregates. In addition to the light weight it has great strength, giving in excess of 4,000 pounds per square inch (in 28 days) in mixtures required in ship construction as compared with 2,000 pounds per square inch for concrete used in ordinary building construction. This aggregate also makes a concrete having an impermeability equal to or greater than sand aggregates. The coefficient of efficiency (deadweight divided by total displacement) of the concrete ship of present design using the light weight aggregate is about 60 per cent.

A Portland cement ground to a greater fineness is specified for ship construction. This cement has greater strength and produces a concrete of greater plasticity and less volumetric change than normal cement.

While the concrete does not require any special treatment in order to make it impervious to water or ordinary crude oils, it will not hold the lighter oils unless the concrete is of exceptional quality. As a further guarantee of imperviousness, we propose to apply a coating of spar varnish to the concrete which will make it impervious to all mineral oils.

We have only indirect experience from which to judge the probable life of the concrete ship. We do know that under certain conditions of exposure the reinforcing steel of concrete exposed to sea water will corrode. We have no precedent with the rich cement mixtures which we propose to use which in themselves may provide all the protection necessary, but as an added precaution we have developed some paint coatings to be applied to the surface of the concrete. The paints which we are using are as follows:—

A priming coat of magnesium fluosilicate ($MgSiFl_6$) is applied to the entire hull. The solution shall contain not less than 15 per cent by weight of salt and not more than one per cent of any other substance in solution, nor more than 0.2 per cent of total chlorine. The paint which will give the best service has not been determined upon. Two types are being tried. One is a high grade spar varnish which is applied in two coats, and the other a bituminous paint consisting of asphalt base thinned with petroleum distillate. One or two coats of this latter is applied followed by a coat of the same paint thickened with about 15 per cent of finely powdered silicious matter and 15 per cent short fibred mineral asbestos. An antifouling paint is applied on under-water parts and a boot topping paint on upper portion. The interior of the tank ships is coated with two coats of spar varnish.

Not less important than the design and material problems are the construction problems. While a concrete ship is composed of steel bars and concrete, never before have we attempted to build structures with such proportionately large quantities of reinforcement, with steel to be bent very exactly in irregular curves, concrete to be placed around this great mass of steel in very thin walls, with few or no joints, and forms to be built to exact and irregular curves.

It is a task of great magnitude and deserving of much study. In this connection we have had specialists working upon the form construction, steel fabrication and concrete placing problems, and have made many tests and investigations.

Another important field of the work of the Emergency Fleet which will especially interest you is the investigation of the stresses in the hull of a ship at sea. This work is under the direction of F. R. McMillan.

In its solution attempt is being made for the first time in the history of naval architecture, except for a single test reported by Biles, to establish experimentally a basis for scientific analysis of hull stresses. This work involves not only the planning and carrying out of tests on a scale not heretofore attempted in any structural investigation, but also the development of special recording instruments for the measurement of strains in any part of a hull under conditions encountered in a storm at sea.

Progress to date has been satisfactory. The Strainagraph, a recording strain gauge, as shown in Plate 110, has been developed, which has proven thoroughly successful. A recording pressure instrument specially adapted for measurement of wave pressures on the hull of a ship has also been perfected. Twenty-five of the former instruments and thirteen of the latter are being provided for the test of the "Liberty" ship now under construction at Brunswick, Georgia. Other arrangements for this test, which is planned to be very extensive, are well under way.

As a preliminary to the important tests to follow, advantage was taken of the opportunity offered by the maiden voyage of the Faith to try out the instruments and to further develop the methods of test. For this test nine strainagraphs were available. The records taken by these instruments simultaneously at nine different points in the ship were synchronized so that the exact stress at any instant at each of these points is known. The voyage of the Faith from San Francisco to Seattle, May 22

to 29, 1918, thus becomes a notable event in the annals of naval architecture; notable, not alone as the first voyage of the first large concrete vessel, but as the occasion when definite and reliable stress records were first obtained on a ship at sea.

A section of one of the autographic records is shown on Plate 111.

Some of the typical features of several of the concrete floating craft which have been designed by the Emergency Fleet are shown in the accompanying illustrations. (Plates 112 to 129.)

The present status of the concrete ship is as follows:—

1. All analytical investigations so far made demonstrate that the concrete ship can be designed so as to carry all the strains which come upon a ship just as safely as a steel ship.

2. The tare weight of a concrete hull has been reduced to such an extent by the development of a light weight aggregate that it has a proportionate carrying efficiency greater than wooden ships and only slightly less than steel ships.

3. All available experience with concrete ships to the present time does not demonstrate any structural weakness which might indicate unsoundness in the theory of design of concrete ships or probable limited life.

4. While ships of small size are being built in many places throughout the world, the large ship (over 3,000 tons) is being developed in the United States.

5. There is no perceptible difference in the frictional resistance offered by a concrete ship as compared with a steel ship.

6. Our general knowledge of reinforced concrete as compared with steel structures makes the success of its further adoption for ship construction appear a certainty, but actual experience is lacking and therefore its future cannot be predicted with absolute certainty.

DISCUSSION.

The President:—This paper, No. 12, entitled, "Present Status of the Concrete Ship," is now before you for discussion.

Mr. E. H. Rigg, *Member:*—Mr. President and gentlemen, I have a few remarks which I have committed to paper—they are not extensive, and will not take up much time to read. However, before I read what I have written, I think it can be safely stated that the concrete ship has definitely arrived within a certain range. The concrete barge and the small self-propelled coasting vessel of reinforced concrete are unquestionably successes. They have been developed in countries that are not rich in iron, and that form of construction has proven satisfactory. They also have a distinct war value in releasing steel and iron for other purposes. When you come to ocean-going ships of relatively large dimensions, that is something else; I do not propose to detain you with a discussion on that point because there has been a great deal published of late on the subject. The transactions of the Institution of Naval

Architects (London) for 1918 contain two valuable papers which were contributed this spring.

The first paragraph in Mr. Wig's paper, summarizing the work being done at the present time, is one which will attract the attention of this meeting. Doubtless there are many points in Mr. Wig's paper which will be commented upon, but there are two points to which I should like to call attention. The first one is at the bottom of the first page, in which he states that it has been necessary to devote much time to the theoretical analysis of the concrete ship structure, which is not undertaken at all in steel ship design. This statement appears to me to be unwarranted, as examples of laborious investigations into the structure of steel ships are well-nigh legion.

Now it is perfectly true, for every steel ship that is built, elaborate calculations are not made, and why? For the simple reason that we have built so many that if we were to attempt to figure out in detail the stresses involved in ordinary ships, which are perfectly familiar to us, and of which we have built hundreds and thousands, we would be unwarrantedly wasting time. That, I think, is a position which can be made good with regard to ordinary ships.

Anyone who has seen the mass of data and the endless calculations on record in the archives of the leading classification societies will know that Mr. Wig's statement is incorrect. I have seen some of the stress calculations undertaken at the time of the design of the Mauretania and Lusitania. I have also seen some of the calculations involved in the design of the battle cruisers at present under contemplation for the United States Navy. These two examples do not stand alone by any means. Reference can well be made to the laborious investigations of the British Bulkhead and Load-Line Committees. The mass of data of exceptional value worked up under the auspices of those committees will serve also to refute the statement. Perhaps Mr. Wig refers only to cargo ships of small size.

Investigation into the question of oil steamer design (which class of ship represents, perhaps, the most difficult of cargo-carrying vessels) will repay the seeker after light on the subject of the investigations which have been undertaken in steel ship design. The work of Mr. Isherwood alone in this field is tremendous, and his work has been supplemented by much investigation on the part of those who have built ships under the longitudinal system of framing.

There is a book called "Structural Design of War Ships" by a fellow-member of this Society, Captain Hovgaard. A very cursory perusal of this book will show Mr. Wig how mistaken he is in his statement.

The transactions of this Society and of its sister Society, "The Institution of Naval Architects" (London), to say nothing of the societies of Continental Europe and Japan, will further show how unjust the statement is.

Passing to the other side of the equation, namely, the forces set up by the sea and by wave action in vessels, these questions have been the subject of extensive study, and if time permitted I could quote a long list of papers, etc., bearing on the subject. It would take very considerable time to merely read the titles of these investigations.

It is to be remembered that the concrete engineers inherit the whole of this field of investigation, which has been laboriously built up by wood, iron and steel shipbuilders and those associated with them in the development of the art. General technical science had not advanced as far when the steel ship began to sail the sea, and our concrete friends would do well to recall this fact. They started in or about this present year of grace, with a field one hundred times as well developed as that with which even the steel shipbuilders started.

Another series which can be quoted as on record in our transactions, and in the transactions of kindred societies, is that of numerous metallurgical papers, all of which are open to the use of the present day shipbuilder.

There is another sentence on page 194 to which I should like to draw attention. Mr. Wig states that except for a single test recorded by Sir John Biles there is no record of any attempt to establish experimentally a basis for scientific analysis of hull stresses. In this statement also a substantial injustice is involved. Investigation of stresses in ship structures at sea is a subject which can well be extended, but it is a fact that a great deal has been accomplished by the unostentatious and sometimes expensive experiences of shipowners and classification surveyors. The records of the classification societies are full of the results attending the operation at sea of countless ships. To cover in only a small measure the available data on the subject, I may refer to the transactions of this Society for 1913 and of the Institution of Naval Architects for 1905, 1906, 1911, 1913, 1914 and 1917. By this I do not mean to say that all these investigations were undertaken exclusively at sea; they include also the record of laboratory and other tests carried out from time to time, and which are fully as important as sea tests. In mentioning these few instances I do not pretend in any way to adequately cover the field.

The Society is to be congratulated on having this paper presented to it, which forms an interesting counterpart to several papers on the same subject recently contributed to the transactions of kindred societies.

The President:—Is there any further discussion? Mr. Wig, do you care to say anything in reply?

Mr. Wig:—I think I can clear up the statement of the previous speaker. The English in the last sentence on the first page of my paper is poor—it was not intended to convey the meaning that investigations have not been made, and are not being made, on steel ships. We not only recognize that they have been made, but we have used many of the investigations to which the speaker referred, and the meaning intended to be conveyed in my paper is that we make in the design of concrete ships many calculations which are not made in steel ship design, under ordinary conditions, such, for example, as complete analysis of frames. It is not intended to convey the idea that this is original with us, but rather that steel ship designers do not commonly make complete investigations and calculations of their structural members.

The President:—If there is no further discussion, I will tender to Mr. Wig, in your behalf, the sincere thanks of the Society for his very valuable paper. We will now pass to paper No. 13, entitled, "The Application of Electric Welding to Ship Construction," which will be presented by Mr. H. Jasper Cox, Member.

Mr. Cox presented the paper.

THE APPLICATION OF ELECTRIC WELDING TO SHIP CONSTRUCTION.

By H. Jasper Cox, Esq., Member.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

INTRODUCTION.

Few subjects offer as great inducements for experimental research as that of the application of electric welding to shipbuilding and marine engineering, and it is doubtful whether, in the whole range of applied science intimately concerned with practical developments in both these industries, there is scope for greater potentiality than under the various headings into which the subject of electric welding naturally divides itself.

Although electric welding, and especially arc welding, has been used for a long time to great economical advantage in ship repair work and marine engineering, it has been but little understood, and to say that only within recent months has any serious attempt been made to analyze the elements of the art and determine the underlying scientific principles involved is not overstating the case.

The skill of the operator was too long the determining factor in forming public opinion on welding, when scientific analysis would have demonstrated that the percentage of failures was largely due to vain endeavors to apply the welding process in defiance of natural laws. Good welds have been made for years, but, in the haphazard application of the art, worthless work was sometimes turned out for which no other explanation can be offered than the welder's ignorance of the physics of his art. As evidence of the good results to be expected from the determination of correct practice in welding, we need but turn to the high degree of efficiency prevailing in railway shops where electric welding has for many years been used on a large scale, both in the construction and repair of locomotives and rolling stock, and where the work consists of repeat operations of the same job, so that there has been established a standard practice evolved through the process of examination and elimination.

In marine repairs, electric welding has long been in use for such work as fractured sternposts, rudders or plates, but owing to the element of uncertainty referred to above, these repairs have usually been considered tentative and approved subject to periodical inspection. In general, however, the periodical inspections have shown that such repairs withstand the test of service and time; thus, in spite of these unknown elements, confidence has gradually been established.

The subject of electric welding received considerable impetus in this country

through the splendid work performed by the United States Navy in refitting for service the seized German ships damaged by their crews with the intent of putting them permanently out of service. Almost without exception the work of vandalism consisted of damaging the cast-iron parts of the machinery equipment in the belief that cast-iron could not be welded by any method available in this country. But the naval officers in charge of the repair work showed that Americans could weld cast-iron. The repairs were carried out with remarkable ease, expedition and success, and while by no means analogous to the problem of welding in its application to ship construction, the results attracted widespread attention to the art in marine circles throughout the world and brought into prominence its possibilities in connection with our shipbuilding program.

About this time, the General Engineering Committee of the Council of National Defense was investigating the application of spot-welding to ship construction. In January of this year the committee was dissolved and the Electric Welding Committee of the United States Shipping Board, Emergency Fleet Corporation, was appointed to investigate the whole field of electric welding and to advise the Emergency Fleet Corporation as to how the shipbuilding program might be speeded up and work economized by a wider adoption of the process.

The committee is composed of shipbuilders, electrical engineers, many prominent physicists and metallurgists, and of representatives of the Emergency Fleet Corporation, Classification Societies and Bureau of Standards, with Professor Comfort A. Adams, of Harvard University and the Massachusetts Institute of Technology and President of the American Institute of Electrical Engineers, as chairman.*

Much useful work has already been accomplished by the committee, data collected, investigations and research work carried out and important facts established. In the meantime similar investigations and research work were being conducted abroad, particularly in Great Britain, where an exhaustive series of practical experiments has recently been completed by the Technical Committee of Lloyd's Register of Shipping.

The results of these investigations have been not only encouraging, but have led to the conclusion that, under certain prescribed conditions, an electrically welded joint may with reasonable safety be applied to the main structure of a vessel.

For several months past, the writer has had the great privilege of participating in the pioneer work undertaken by the Welding Committee, and it is the purpose of this paper to review as briefly as possible what has already been done and the immediate possibilities of its further application to ship construction in the light of the present development of the art of electric welding and the knowledge thus far acquired; embracing in this necessarily short review a description of the various methods of welding, the apparatus and layout involved and minor practical features.

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*Representatives of the gas welding industry have recently been added to this committee, and the title changed to "The Welding Committee."

METHODS OF WELDING.

The methods of electric welding applicable to ship construction can be divided under two main headings, resistance welding and arc welding.

Resistance Welding.

As the term implies, it is the resistance offered to the flow of electric current through the material and contact surfaces to be united which causes the metal in the path of the current to heat up to the necessary temperature. Welding is then accomplished by the application of pressure. The heat is largely localized in the weld by the use of clamping electrodes of low resistance and by the additional resistance in the contact surfaces themselves as compared with the solid metal. Alternating current of relatively high amperage and low voltage is used and the pressure applied either hydraulically, pneumatically or by hand, depending upon the size of the job.

There are two distinct kinds of resistance welding—spot welding and butt welding.

(*a*) *Spot Welding.*—Spot welding has been extensively used for jointures of thin sheet metal such as ventilators, lifeboats and railway cars with considerable success, but it is only recently that its application to plates and bars of the thickness required in ship construction has been investigated.

The two or more pieces to be welded are overlapped or superposed in way of the joint and clamped between two copper electrodes; the current is passed through and pressure applied. In order to ensure a successful weld the pressure should be sufficient to cause the metal to "flow" at the weld and to extrude all oxides, slag, etc., which may form. The pressure is maintained for a short time after the current is cut off, and the operation is then repeated at the next spot, and so on.

Small buttons or discs of metal are sometimes placed under one or both of the electrodes and when of proper thickness are completely submerged in the plate metal during the operation of forming the weld.

As in smith welding, what is going on at the welding surfaces cannot be seen, and although the material may have been properly prepared, the success of the operation obviously depends upon:—

(1) The amount of current applied to produce the proper heat throughout the various stages of the operation.

(2) A sufficient pressure to weld the surfaces and extrude oxides, gases, etc., without undue distortion of the material.

(3) Sufficient time being allowed.

(4) The size and type of electrodes used.

In light work these variables have to a great extent been determined by extensive practice and experience, but in the heavier material used in ship construction there has, until recently, been little or no experience available.

However, the advantage of successful application of this method of uniting ma-

terial to the exclusion of marking off, punching, reaming, countersinking and riveting in the fabrication shops, and even on the ship itself, is obvious. It is also patent that if the quantitative values of the above variables necessary to produce a perfect weld are definitely determined for all thicknesses of material, the operation becomes not only entirely mechanical but also uniformly efficient.

Intensive research work is now being conducted along these lines by the General Electric Company, which has built a heavy spot welding machine with a capacity of 100,000 amperes at 20 volts and a hydraulic pressure of 36 tons at the electrodes.

Owing to the necessity of providing a gap large enough to deal with the width of plates necessary in ship work, a number of practical difficulties were encountered in the design of the machine. One important development in this connection has been the elimination of the variable reactive drop caused by the varying inductance created in the circuit due to the width of plate within the gap. This necessitated a change in voltage for different widths, but by using two sets of electrodes and two transformers, one on each side of the work with leads direct to the electrode on the same side, the secondary windings of the transformers are in series and the effect of varying widths of plates is eliminated. Moreover, the total reactive drop is greatly reduced, which permits of a corresponding reduction in the size and weight of transformer and generating apparatus. With the two sets of electrodes two spots are welded at a time, or a dummy can be placed between the second pair of electrodes if necessary.

A careful series of experiments is being carried out with this machine, using plates of from ¼ inch to 3 inches total thickness, and that satisfactory spot welds can be made within this range has already been demonstrated.

It has been found that an appreciable range is permissible in the variables of current, pressure and time without seriously impairing the efficiency of the weld for a given thickness of material.

Where considerable *tensile* pull is anticipated in an over-lap joint, it is considered desirable to have a double row of spots to prevent the tendency to bend and tear out the spots in the same manner as the countersunk heads of rivets are sometimes torn through the holes in a single riveted over-lap.

Plates 130 and 131 are illustrations of joints made during these experiments, which, at the time of writing, are still proceeding with the probability of obtaining definite and comprehensive data at a very early date.

The 42-foot section of a 9,600-ton vessel to be built at the plant of the Federal Shipbuilding Company, Kearny, N. J., and to which reference will be made later, will be used to demonstrate the practicability or otherwise of this method of welding as applied to the assembly of material in ship construction.

A stationary spot welder will be used in the fabrication of the parts, and a large 60-inch gap portable spot welder is being completed which will be used both for clamping the parts together in the field and spot welding them in place. This machine is illustrated in Fig. 1, Plate 132.

It will be seen, therefore, that although this method of welding has not yet

reached the stage of development which might warrant its practical application to ship construction, it offers every prospect of doing so within the very near future.

Obvious developments with this system are multiple spot and continuous or seam welding, both of which will tend towards great saving in time.

In general spot welding is much more rapid than arc welding and requires less labor, but more power and a much heavier and more expensive machine.

(*b*) *Butt Welding.*—This system of resistance welding is especially applicable to bars of uniform section and will probably be used extensively in jointing reinforcements in ferro-concrete construction.

The bars to be welded are brought together, end on, clamped and a low-pressure current passed through until a welding heat is obtained. Then end pressure is applied until the metal at the joint shows signs of squeezing out. A machine for this type of welding has been ordered by the Emergency Fleet Corporation and will be tried out during the construction of a 3,500 D. W. T. reinforced concrete steamer building by the Fougner Concrete Shipbuilding Company.

Electric Arc Welding.

In this method of welding the electrode and the material to be welded are connected in a simple electric circuit and an arc is struck by bringing the electrode in contact with the work at the point where the weld is to be made, then withdrawing it slightly to obtain the desired length of arc.

The two principal methods of applying this process are by means of:—(*a*) the carbon arc; (*b*) the metallic arc.

In the former a carbon electrode is used and the heat from the arc produced brings the metal to a fusion heat. When welding with the carbon arc additional metal is introduced into the arc and fused into and with the parent metal at the joint. Its main field of application, however, is in rough cutting in foundries and steel mills and for the repair or building up of imperfect castings.

It has not been advocated for use in ship construction generally and there are a number of reasons which make it doubtful whether it ever will be.

In metallic arc welding a metal electrode is used of approximately similar material to that being welded, the electrode itself is fused by the arc, and molten particles are carried over the arc into the fused portion of the parent metal, thus gradually building up the joint.

The actual operation, however, is not quite so simple as this sounds, for there are a large number of variables, any one or any combination of which may affect the efficiency of the result to a greater or less extent.

These variables may be enumerated as follows:—

1. The type of electrode, *i. e.*, bare metal or covered.
2. Chemical composition of the electrode.
3. Chemical composition of metal being welded.
4. Size of electrode.

5. Kind of current, *i. e.*, alternating or direct.
6. Amperage and voltage.
7. Skill of the operator.
8. Method of preparing and building up the joint.

1. In regard to the first, it may be said that good welds have been produced by either, but the covered electrodes have been found to produce, in general, a more ductile weld, a very desirable quality in ship construction.

There are two distinct types of covered electrodes known as the gaseous flux and the liquid flux. The former, developed by Kjellberg, is covered with a fireproof sleeve of non-conducting material which projects sufficiently far into the arc to protect the heated end of the electrode metal from oxidation by the atmosphere, guiding the molten metal direct into the arc and reducing heat losses.

In the liquid flux process the covering melts with the electrode, forming a molten flux over the end of the electrode and over the added metal, thus protecting both from oxidation from the air. This flux by reducing chilling, in a measure, serves an annealing function, but its chief value seems to be the protection from oxidation with the accompanying brittleness and porosity caused by the reaction of the oxygen on the carbon and iron of the molten metal. The solidified flux is chipped and brushed off before building up the next layer.

There are a large number of different makes of liquid flux covered electrodes on the market, but it is not proposed here to go into their respective merits or drawbacks. Careful investigation and experimental work are being carried out by the Welding Committee with most of the known makes, and the results will be published in due course.

2. The chemical composition of the electrode is to-day considered to be a most important variable, and after an exhaustive series of tests the Welding Committee has drawn up the following tentative specification for electrodes intended to be used in welding mild steel of shipbuilding quality:—

Chemical Composition.—Carbon, not over 0.18 per cent; manganese, not over 0.55 per cent; phosphorus, not over 0.05 per cent; sulphur, not over 0.05 per cent; silicon, not over 0.08 per cent.

Sizes:—

Fraction of inch	*Lbs. per foot*	*Feet per lb.*	*Lbs. per 100 ft.*
1/8	0.0416	24	4.16
5/32	.0651	15.35	6.51
3/16	.0937	10.66	9.37

Allowable tolerance .006 plus or minus.

Material.—The material from which the wire is manufactured shall be made by any approved process. Material made by puddling process not allowed.

Physical Properties.—Wire to be of uniform homogeneous structure, free from segregation, oxides, pipes, seams, etc., as proven by micro-photographs. This wire may or may not be covered.

Workmanship and Finish.—(*a*) Electric welding wire shall be of the quality and finish known as "Bright Hard" or "Soft Finish." "Black Annealed" or "Bright Annealed" wire shall not be supplied. (*b*) The surface shall be free from oil or grease.

Tests.—The commercial weldability of these electrodes shall be determined by means of tests by an experienced operator, who shall demonstrate that the wire flows smoothly and evenly through the arc without any detrimental phenomena.

Further reference emphasizing the importance of this factor will be found later under the Rules of Lloyd's Register of Shipping.

3. The chemical composition of the material to be welded is a quantity over which we have no great control, but open hearth mild steel of the quality under consideration has usually sufficient uniformity in its chemical composition to permit a general application of the foregoing specification.

However, the effects of varying carbon and other contents, including occluded gases, are being carefully investigated with a view to obtaining a more complete knowledge, and it is considered that a true understanding of the successful arc weld will result only from a combination of metallurgical and electrical study.

4. The size of the electrode in relation to the current strength and the thickness of material to be joined is also a matter of obvious importance.

While it has not yet been thought expedient to standardize these relations, the following table published by the Quasi Arc Weltrode Company may be found of interest:—

ELECTRODES AND CURRENT REQUIRED FOR SHEET AND PLATE WELDING.

Thickness of work	Preparation of joint	Size of electrode	Current in amperes
		Inches	
16 S. W. G.	Close joint	0.08	20 to 25
14 S. W. G.	Close joint	.105	30 to 35
12 S. W. G.	Close joint	.105	40 to 45
10 S. W. G.	Close joint	.135	50 to 65
3/16″ plate	1/16″ open	.135	75 to 95
1/4″ plate	Veed half-way through and 1/32″ open	.16	93 to 110
5/16″ and 3/8″	Veed right through to 70° and 1/16″ open. Two runs are necessary—		
	First run	.135	75 to 85
	Second run	.16	93 to 110
1/2″ plate	Veed right through to 60° and 1/8″ open. Two runs are necessary—		
	First run	.135	75 to 85
	Second run	.192	100 to 120
5/8″ and 3/4″	Veed right through to 60° and 1/8″ open. Three runs are necessary—		
	First run	.135	75 to 85
	Second run	.16	95 to 110
	Third run	.16	100 to 120

For heavy plates it is advisable to vee half-way through from both sides if practicable.

The current varies to some extent with the thickness of plate and type of electrode, bare electrodes requiring a higher amperage than covered.

5. The kind of current, whether alternating or direct, has occasioned considerable controversy, and while a direct current of a given open circuit voltage will permit of a slightly greater length of arc, the advocates of the alternating current claim that, since proper fusion depends upon the maintenance of a short arc, alternating current is preferable as the arc itself will break if lengthened too much.

As, however, efficient welds can be made by either, the question is more one of economy, ease of operation and convenience in the supply of current. This will be briefly referred to when describing the types of apparatus.

6. The amperage should be adjusted to suit the size and type of electrode and will be found to increase slightly with the thickness of material being welded; if too great for the size of electrode used the fusion will not be uniform and steady, the electrode itself tending to "spatter," while if the amperage is too small, a proper fusion temperature will not be reached.

The voltage increases with the length of arc and, in order to prevent this length becoming greater than is desirable for efficient welding, a number of machines and controls have been designed which automatically break the current if the arc is drawn out beyond the desired length. The range of length of arc usually adopted is from 1/8 inch to 3/16 inch and the voltage varies from 15 to 25 with bare electrodes and from 30 to 40 with some types of covered electrodes.

7. The skill of the operator or human element is still the most vital factor, and it is probably because of this that arc welding is known as an art rather than a science.

The density of current, and therefore the heat density of the arc, decreases as the length of the arc increases; a short arc, in general, results in a high temperature and virtual vaporization of the metal, while a long arc is apt to lead to the deposition of large drops or "beads" of electrode accompanied by oxidation. Consequently a varying length of arc naturally results in a lack of uniformity in the character of material in the weld.

As, however, scientific investigation determines the effect of each of the above-mentioned variables, it will be possible to predetermine and specify with more exactness the ideal conditions under which a successful weld is assured, assuming that the arc is held at constant length. Until such time we must remain largely dependent upon the skill of the operator, not only in maintaining the constant length of arc, but also in determining a most desirable current adjustment for the work in hand.

It may be interesting at this point to mention that automatic, self-feeding welding machines have already been designed and are now being experimented with. These machines will not only eliminate the factor of varying length of arc but will result in a considerable increase in speed of operation.

An illustration of the type of work done by a stationary automatic welder manufactured by the Automatic Arc Welding Company of Detroit, Michigan, is shown

in Fig. 2, Plate 132. At the time of writing, the makers of this machine and others are engaged in the development of portable automatic welders, about which we shall no doubt hear more in the near future.

8. The preparation and building up of the joint have considerable bearing not only on the ultimate strength of the weld itself, but on the time and cost of making it.

Correct preparation of the joint for welding is just as important, if not more so, as in the case of a riveted joint. The time and cost of welding depend largely on the amount of electrode material deposited, and therefore the joint should be prepared so as to require the minimum amount of building up consistent with the necessary strength and accessibility. Plates 133 and 134 show a number of typical welded joints which may be met with in ship construction with a brief description of the method of preparing and welding as recommended by the Welding Committee.

In large plates where a long joint, such as a seam, has to be welded, the contraction set up in cooling tends to draw the joint together, and, unless proper precautions are taken, the plates will tend to fold over one another at the end away from that being welded.

Two methods to counteract this are generally adopted. In the "non-rigid" method the two plates, instead of being placed parallel with the joint, are diverged to the extent of about 1/8 inch to the lineal foot of weld; as the welding proceeds from one end, the plates gradually close together without setting up any great initial internal stresses. This method obviously introduces a number of practical difficulties if applied to the main construction of a vessel.

In the "rigid" method the joint is tack welded at intervals along its length and the welding done, not continuously from end to end, but in separate stages so as to distribute the heat, as much as possible, uniformly along the joint.

An interesting method of building up a "rigid" joint in order to reduce the internal contraction stresses is indicated in Plate 135, where it will be observed that each side of the joint is separately built up, the deposited material from the electrode being entirely free to contract on one side, leaving only the "closing in" run of metal which is small and which is bonded on each side of the joint.

WELDING APPARATUS.

The types of apparatus manufactured for electric arc welding may be divided into three main classes:

1. *Motor generator sets* operating from A. C. or D. C. mains and designed to generate a suitable voltage. These machines are generally supplied with controls which automatically adjust the current to the length of arc operating.

Examples of these machines are illustrated in Figs. 1 and 2, Plate 136.

The first is a 4-arc D. C. motor generator set of 15-kilowatt capacity manufactured by the General Electric Company. With this machine four balancer sets and control panels are supplied, which it is claimed give thorough protection to the gen-

erator without affecting other operators whose welding circuits may be connected to the same generator.

Figure 2 illustrates the "Naval" type one-arc D. C. portable motor generator set manufactured by the Wilson Welder & Metals Company. This machine has a capacity of 150 amperes at 35 volts, and with the control panel weighs about 1,900 pounds.

2. *Stationary transformer sets* operating A. C. only, as illustrated in Plate 137. This is a one-arc set manufactured by the Electric Arc Cutting & Welding Company, of Newark, N. J., and, as will be observed, is compact and portable, weighing about 230 pounds, and easily carried by two men. This machine has a capacity of 4 kilowatts, is designed to maintain a constant wattage, and can be used with practically any A. C. main supply.

3. *Resistance control.* This is the simplest of the three types and consists generally of a simple cast iron resistance grid which reduces the voltage from the main to that required at the arc, the difference being wasted.

Where the main supply is over 110 volts, however, it is necessary to employ a motor generator set or rotary converter, or in the case of A. C. current a static transformer, as the waste would be prohibitive. Plate 138 illustrates a complete outfit as supplied by the Quasi Arc Weltrode Company, the weight being about 250 pounds. The current for each welder can be taken anywhere from the main with a common earth for all arcs.

It will be seen, therefore, that there is a great divergence in type, portability and, needless to say, in cost of apparatus advocated by the various manufacturers of arc welding outfits and, since they all claim to make a satisfactory weld, it would appear that the question of selection devolves into one of economy of first cost, power efficiency, and portability. In this connection it is important to bear in mind that, while the simple resistance method is the least efficient electrically, its overall efficiency is increased, due to the current saving when the arc is broken, and in practice this probably represents about 50 per cent of the total time.

The cost of wiring the shipway or shop is approximately the same with all systems.

The average apparatus will work at about 6 to 8 kilowatts per welder when welding, but if low voltage is provided at the mains, there are certain outfits which are said to reduce the consumption to as low as 3½ kilowatts or even less.

SPEED AND COST.

Unfortunately there are as yet very little reliable data of a general nature in regard to the speed and cost of welding on straight-line work in the field. Again, there are so many varying factors which enter into the question that any figures can only be considered with due regard to the particular conditions under which they were obtained.

The following figures have been computed from some data obtained in England by Capt. James Caldwell, R. E., on work done in the field during the construction of an all-welded barge recently built at Richborough.

The figures have been adjusted to suit the present cost of welding labor and electrode material in this country, which differ considerably from those obtaining in England:—

METAL ELECTRODE ARC WELDING (QUASI ARC).

Plate thickness	Power used per foot run, amps. at 100 V.	K. W. H. at 3c	Electrode per foot run in cents	Labor at 65c per hour	Time per foot of weld	Speed in feet per hour	Total cost per foot of weld in cents
1/8″	55 amps.	0.54c	7	2.165c	2m.	30	9.7
1/4″	100 amps.	1.35c	12.9	2.954c	2m. 45s.	22	12.2
3/8″	100 amps.	4.8c	19.2	8.66c	8m.	7.5	32.66
1/2″	120 amps.	7.2c	25.5	13.00c	12m.	5	45.7

Other figures prepared by the Welding Committee show the possible cost of a fillet weld on a ½-inch plate, using a motor generator set and bare electrodes, to be as follows:—

Average speed of welding on continuous straightaway work..... 5 ft. per hour
Amount of metal deposited per running foot .....0.6 lb.
Current 150 amps. at 20 volts = 3 kilowatts.
Motor generator eff. 50% = 6 KW ÷ 5 equals ..... 1.2 K.W.H. per 1 ft. run
1.2 K.W.H. at 3 cents per K.W.H. equals..... 3.6c per ft.
Cost of electrode 10 cents per lb. and allowing for waste
ends, etc., equals..... 7.2c per ft.
Labor at 65 cents per hour equals.....13.00 per ft.

23.8 per ft.

The curves plotted in Plate 139 are the results of data collected by the Quasi Arc Weltrode Company, and show the lineal feet per hour of straight line flat welding for different thicknesses of plates together with percentage corrections for vertical and overhead welds. These results were obtained under laboratory conditions, however, and for bulk work in the field or shop it might be advisable to reduce them by a considerable margin, even as much as 50 per cent.

The protection of the worker on ship work in the field is one which will require careful study. The welder himself must be provided with a hand glass or mask which, while adequately protecting his eyes and body from the arc and falling metal, will not impair his movements while working on high stagings in all weathers. Arrangements should also be made to protect his neighbors or other workers from exposure to the arc.

TRAINING OF WELDERS.

We have seen that skilled workmanship is essential to good welding and, in the absence of any definite means of testing finished work in the field, conscientious workmanship is equally important. A skilled and properly trained welder knows instantly whether or not he is making a good weld. He can tell this by the smoothness of the flow of metal, the uniformity of the sound and light of the arc, and by the lack of "spattering" or deposition of "beads." When his arc is not welding he should immediately cease work, remedy the cause, whether it be unsuitable current control or faulty electrode, and, before proceeding again, should chip out the bad work, especially where the arc was broken. Thus it will be seen that the welder should possess some knowledge of the elements of electricity, how it is generated, conducted and controlled, the melting point of the metals employed, and the properties of the particular electrode in use. In ship work he should understand the correct methods of preparing the various joints and their relative importance, together with the best methods of building them up. It is therefore a *sine qua non* of welding the main structure of a vessel that only skilled operators be used. Recognizing this, the Emergency Fleet Corporation has established a separate training and education department for electric welding and has opened schools for the training of operators and instructors at New York, Newport News, the Great Lakes, Schenectady, San Francisco and other centers throughout the country, where selected men may be sent from the various shipyards and engine works to undergo a course of intensive training as operators or instructors. On the satisfactory completion of this course, and when possessing the required degree of skill, these men are certified and returned to their places of employment.

Owing to the great shortage of welders it is hoped that in time each shipyard will have its own school with a competent instructor in charge who has been trained at one of the E. F. C. schools, and a force of efficient welders may gradually be built up in this manner.

A photograph of one such school, as established at the plant of the General Electric Company, Schenectady, is shown in Plate 140.

INSPECTION.

This subject may be considered under three headings:—

1. Inspection and testing of the electrodes being used.
2. Inspection of the work before and during welding.
3. Inspection of the completed welds.

We have already seen that the chemical composition and quality of the electrodes used have an important bearing on the quality of the weld produced, and care should be taken to see that only electrodes of the correct chemical compositions are used; that the wire is of proper size and of uniform homogeneous structure, free from segregation, oxides, pipes, seams, etc.; that the surface is

clean, and that the wire flows smoothly and evenly through the arc without any detrimental phenomena.

All work should be examined and approved before welding commences in order to see that the joints are properly prepared for the particular kind of weld to be made, that the edges are properly fitted or spaced and the work properly closed up.

In the thicker plates the first run of metal or "foundation" weld should be made with a small wire, carefully examined for flaws or defects and passed upon before the next layer of metal is added. This inspection should be carried out by specially trained supervisors, who should also watch the welding in operation, check up the current at the meters, and see that bad welds are cut out where required.

The proportion of supervisors to operators will depend largely upon local conditions, grouping and experience, but at present one supervisor to each six or eight operators in the shop and one to each four or five operators in the field are being tried.

Various methods have been suggested for the inspection of completed welds, and the Research Committee of the Welding Committee is at present investigating a number of these, including electric resistance, magnetic, X-ray, and acoustic methods, but the problem is extremely difficult and has not yet shown indication of any satisfactory solution.

In practice the usual tests applied are by blows from a hammer or by chipping at intervals with a cold chisel or pneumatic tool. Either of these methods will usually detect a really poor weld approaching zero efficiency, but neither can be relied upon to indicate the value of a joint which, while not absolutely bad, does not reach the standard of efficiency required in a particular case. For this reason it is most necessary to rigidly test every material and system of welding proposed before accepting them as suitable for application to important strength members.

PRESENT APPLICATION OF ELECTRIC ARC WELDING IN SHIP REPAIR WORK AND NEW CONSTRUCTION.

The range of application of the arc-welding process to the execution of marine repairs such as the reclamation of broken castings, fractured plates, boiler furnaces and the reinforcement of eroded or badly wasted plate edges and cracked hull plates is so well known and so varied that only the briefest mention is possible within the scope of this paper. A few instances of such application are illustrated in Plates 141 to 143.

Plate 141 shows a repair which was successfully carried out to a broken stern frame gudgeon on a small steamer. The repair was effected in place and obviated the delay and expense of a new stern frame.

Plate 142 shows a method of reinforcing a badly eroded propeller strut and worn bossing. This repair occupied four days and the saving in time and expense compared with that of furnishing a new casting is obvious.

Plate 143 illustrates a salvage operation to fractured end keel plates necessitating overhead welding.

It will be seen that, in the application of electric welding to repair work, a great degree of skill and experience is necessary on the part of the operator owing to the variety of his work. A common cause of failure in such repairs is lack of experience as to the proper preparation of the job and correct methods of counteracting the effects of expansion and internal stresses set up during the operation of welding. For work of this nature an operator cannot be fitted by any system of intensive training in welding alone, but only by a wide experience in ship and boiler repair work in general.

In new construction considerable work of a non-structural character can be more economically effected by electric welding than by the existing methods of bolting or riveting. Work of such character as described below does not involve serious difficulties connected with the quality of welding, and, in addition to the economical aspect referred to, a great advantage to be derived from its adoption in such parts is that in the course of time the men engaged in this work will become trained in the art and a nucleus of welding equipment and of an operating force will be built up in the shipyard which may be used for more important structural work.

With this double purpose in view, the Electric Welding Committee early in the year requested the Classification Societies to draw up a list of the parts of a vessel in which electric welding might be used as an alternative to other methods of attachment without any specific requirements or regulations.

A few examples of non-structural work for which it is suggested that electric welding is specially adapted are the following:—

Deck rail stanchions to plating.

Attachment of clips and hangers for pipes and wiring to casings, bulkheads, etc.

Clips for attaching interior wood fittings to steel work.

Engine and boiler-room stairs and gratings with their attachments.

Masts, derricks, ventilator cowls and trunking.

Cargo batten cleats to frames.

Hatch cleats to coamings.

Small tanks, bins and racks.

Skylights generally.

Manufacture and attachment of storeroom, galley, and cabin fittings.

Welding studs in case armor plating for fitting of attachments.

Anglesmith work can be considerably reduced if the flanges of the angle bars are notched out, bent to the proper angle and electrically welded at the junction. The bending can generally be accomplished cold. Watertight or oiltight collars and the bosom pieces of watertight and oiltight boundary bars on bulkheads and double bottom floors can also be largely eliminated.

Let us consider the first item on the above list, namely, the attachment of hand rail stanchions to deck plating, and particularly in the case of a tank steamer.

The usual method of riveting these stanchions involves the following distinct operations:—

1. The positions of the stanchions are lined off and the holes in the base palm marked on the deck plating by the pipe fitters.

2. The two or three holes, as the case may be, are drilled.

3. Interior scaffolding is erected by the carpenter at the under side of the deck for the riveters' holder-up.

4. The stanchion is put in place, packing inserted and bolted up.

5. Reaming is sometimes necessary.

6. Two or three rivets have to be driven for each stanchion by a gang who in most cases cannot be spared from the straightaway work on the decks, shell, etc.

If electric welding is substituted, the stanchions with their rails inserted are erected in large sections and are welded directly to the deck plating by the operator, who proceeds single-handed with his electric cable from stanchion to stanchion. The watertightness or oiltightness of the deck is not affected, and the efficiency of the attachment itself can readily be tested by blows from a sledge-hammer.

The saving in labor by welding some of the parts in the above list will average more than 60 per cent.

Some illustrations of welding jobs successfully and economically carried out by the Submarine Boat Corporation are shown in Plates 144 to 147.

It may be of interest to mention that the American International Shipbuilding Corporation at Hog Island has now some 50 to 60 men engaged on welding work of this description. They have a training school in the yard with 5 A. C. and 1 eight-arc D. C. machines, and with three instructors are daily turning out more trained welders to add to the above number. The equipment in the yard itself at present consists of 33 A. C. machines, 1 eight-arc D. C. machine and 1 one-arc D. C. machine.

LLOYD'S EXPERIMENTS ON ELECTRICALLY WELDED JOINTS.

The attitude of Lloyd's Register of Shipping towards electric welding has been one of the chief concerns of those advocating its application to the main structure of a vessel. It was felt by some that, no matter what "proofs" or evidence of its suitability were put forward, the Society which the writer has the honor to serve would act in an arbitrary manner and bluntly refuse its recognition until such time as an actual ship had been built and proved successful in service. They did not appreciate the characteristic attitude of the Committee of Lloyd's Register towards all efforts in the direction of mechanical or scientific progress in ship construction, nor their desire to cooperate in such progress and to place at the disposal of the shipbuilding community throughout the world the unbiased services of their highly skilled technical staff.

They did not understand that a ship classification society whose existence is indissolubly linked with its professional independence, untrammelled by any particular or national interest, must perforce keep itself abreast of the latest developments in scientific and mechanical progress, quite apart from giving its stamp of approval to proposed designs or methods of construction.

This disposition, to be conversant of and associated with the many paths of research in the shipbuilding and marine engineering field, however, must not be confused with its primary function, namely, its responsibility to the shipowners, underwriters and merchants who look to it with implicit faith for technical guidance in the conduct of their business.

When, therefore, the development of electric arc welding had reached a stage at which its application to the main structure of a vessel, with all the attendant possibilities, appeared a feasible proposition, the Technical Committee of Lloyd's Register of Shipping, quite in accord with its traditions, immediately embarked upon an exhaustive investigation in order to determine at first hand the suitability of electrically welded joints for such work.

A series of experimental tests was devised and carried out under the direction of the Society's Technical Staff in England, extending over a period of many months. A brief description of these tests and summary of the results have already been prepared and circulated by the committee, but they are of so important and practical a nature that it is not considered out of place to refer to them rather more fully here.

It is commonly accepted that the tests imposed on manufactured material do not in any way represent the strains which may be experienced in practice. Such tests are rather based on simple means for determining the average reliability of the material. Thus, also, in this case no one particular test is likely to determine whether the welding process under trial is sufficient for the work it will probably have to perform.

It is therefore necessary to approach the problem rather on the basis of circumstantial evidence and to decide from a number of different types of experiments whether, on the whole, the performance is satisfactory.

The investigations were undertaken to determine the possibilities of the application of electric arc welding to shipbuilding and, as it was desired to obtain as much knowledge as possible of the physical properties of the combination of rolled and welded material, highly skilled operators were employed.

Thus it should be realized that the results of the experiments which have been made represent skilled practice, and that in general such performance can only be equalled with good workmanship and efficient supervision.

The quasi arc process of electric arc welding was used throughout the experiments.

Nature and Description of Experiments.

The general scope of the experiments included:—

(*a*) Determination of modulus of elasticity and approximate elastic limit.

(*b*) Determination of ultimate strength and ultimate elongation.

(*c*) Application of alternating stresses with (1) rotating specimens, (2) stationary test pieces.

(*d*) Minor tests, such as (1) cold bending of welds, (2) impact tests of welded specimens.

(*e*) Chemical and miscroscopic analysis.

Tests were carried out on specimens as large as possible, particularly in respect to the static determinations of elasticity, ultimate strength and elongation, some of the test specimens being designed for a tatal load of just under 300 tons. The advantage of these large specimens was that the effect of workmanship was better averaged and the results were more comparable to the actual work likely to be met with in ship construction.

Figure 1, Plate 148, illustrates the method adopted to measure the modulus of elasticity by means of a strain meter designed by Dr. James Montgomerie, principal surveyor for Lloyd's Register in Scotland. The photograph shows the holders which were specially designed with a view to securing, as far as practicable, an even pull across the breadth of the plate.

Readings were taken in way of the weld and at various points on the plate itself, both adjacent to and well clear of the weld, the points at which observations were taken being clearly shown in Fig. 1, Plate 149.

Typical results, illustrating the extensions as measured along the line C, are shown in Fig. 2, Plate 149, from which it would appear that the extensions in way of the weld do not show any marked difference from those at various points in the plain plate, the lines showing extensions in way of the weld lying among the others without disclosing any distinctive features. Measurements were also taken with the strain meter set at right angles to the line of pull, the readings in this case, of course, representing contractions (Fig. 3, Plate 149).

With a view to confirming this result a set of specimens of smaller size was prepared and tested. Automatic stress-strain diagrams showing the extensions up to the point of fracture are shown in Fig. 4, Plate 149, while Fig. 5, Plate 149, represents on an enlarged scale the extensions within the elastic limit, the distance between the points of attachment of the instrument being 8 inches in each case. The curves exhibit the same general characteristics as those obtained from the large specimen and would appear to justify the inference that there is very little difference between the modulus of elasticity of the welded samples and that of the plain plate.

With alternating stresses the specimens were relatively of small size. For the rotating test pieces, circular rods, machined from a welded plate, were used, the diameters selected being 1 inch and ¾ inch. These bars, about 3 feet in length, were attached to a lathe headstock, and a pure bending moment in one plane was applied by means of two ball races to which known weights were attached. The material of the bar was thus exposed alternately to maximum tension and to equal maximum compression once in each revolution. The machine was run at about 1,060 revolutions per minute.

Bars of identical material were tried in pairs, one specimen welded and the other unwelded, and the number of revolutions before the specimens parted was observed for various ranges of stresses varying from ±15 tons to ±6 tons per square inch.

The general arrangement of the apparatus is shown in Fig. 2, Plate 148, and a typical example of the results obtained is given in Fig. 6, Plate 149, which shows clearly the stresses at which the welded and unwelded bars will withstand a very large number of repetitions of stress.

In the second series of alternating stress experiments flat plates were used of three thicknesses, viz., ¼ inch, ⅜ inch and ½ inch. These specimens were tried in groups of four, each group consisting of one plain, one butt welded, one lap welded and one lap riveted plate. The specimens, which were about 14 inches long by 5 inches broad, were clamped along the short edges, so that the distance between the fixed lines was 12 inches. Each plate was also clamped, near the middle, to the end of a pillar, which by means of a crank arm was caused to oscillate and to bend the specimen equally up and down by adjustable amounts (the maximum total movement in any of the experiments tried was 5/16 inch). The machine was run at various revolutions (not exceeding 90 per minute), and the number of repetitions at which the specimen parted was observed.

The type of apparatus used in these tests is illustrated in Fig. 1, Plate 150, and typical results obtained are illustrated in Figs. *7a* and *7b*, Plate 149, in which the ordinates represent total displacement from normal position, *i. e.*, 2/16 inch means 1/16 inch up and 1/16 inch down.

Minor tests of various kinds were undertaken, of which the principal ones had reference to the suitability of the welded material to withstand such bending and shock stresses as might occur in the shipbuilding yards. The experiments on bending consisted of doubling the welded plate over a circular bar of diameter equal to three times the plate thickness and comparing the results with those of the plate of the same material, but unwelded.

Figure 8, Plate 149, shows the results obtained from the bending tests, from which it will be noticed that the angle at which fracture occurred decreases rapidly with increased thickness of plate.

In the impact tests heavy weights were dropped from various heights on to the welded portion of a plate 5 feet long and 2 feet 6 inches in breadth, the weld being across the plate parallel to the shorter edge. The deflections were noted and the condition of the weld was examined after each blow.

Other tests to determine the relative value of welding and caulking under tension and the relative bearing value of a riveted or welded lug attachment are shown in Plates 151 and 152. In the former, two plates are attached at right angles by an angle lug with closely spaced rivets and the angle caulked on both edges, similar to the boundary angles of a watertight or oiltight bulkhead. The object of the test was primarily to ascertain at what stress the "tightness" of the attachment was destroyed as compared with that of the welded attachment. The results indicated are very striking.

The test shown in Plate 152, in which a direct shearing force was applied to the lug attachment, indicates the relative values as between riveting and welding a lug attachment for such work as bracket connections.

It will be observed that the welded lug is notched out at its mid-length and the welding applied only at the ends and in way of the notch.

Many other practical tests of this nature were made, but the foregoing are perhaps of greatest interest.

The chemical and micrographical examination followed the ordinary practice.

SUMMARY OF EXPERIMENTAL RESULTS.

1. *Modulus of Elasticity and Approximate Elastic Limit:—*

(*a*) In a welded plate the extensions in the region of the weld are sensibly the same as for more distant portions of the unwelded plate.

(*b*) With small welded specimens containing an appreciable proportion of welded material in the cross-sectional area, the relation between extension and stress is practically the same, up to the elastic limit, as for similar unwelded material.

(*c*) The elastic limit (or the limiting stress beyond which extension is not approximately directly proportional to stress) appears to be slightly higher in welded than in unwelded material.

(*d*) The modulus of elasticity of a small test piece, entirely composed of material of the weld, was about 11,700 tons per square inch as compared with about 13,500 tons for mild steel and about 12,500 tons for wrought iron.

2. *Ultimate Strength and Ultimate Elongation:—*

(*a*) The ultimate strength of welded material with small specimens was over 100 per cent of the strength of the unwelded steel plate for thicknesses of ½ inch, and averaged 90 per cent for plates of ¾ and 1 inch in thickness.

(*b*) Up to the point of fracture the extensions of the welded specimens are not sensibly different from those of similar unwelded material.

(*c*) At stresses greater than the elastic limit, the welded material is less ductile than mild steel, and the ultimate elongation of a welded specimen when measured on a length of 8 inches only averages about 10 per cent as compared with 25 to 30 per cent for mild steel.

3. *Alternating Stresses:—*

(*a*) *Rotating specimens* (round bar)—

Unwelded turned bars will withstand a very large number of repetitions of stress (exceeding, say, 5 millions) when the range of stress is not greater than from 10½ tons per square inch tension to 10½ tons per square inch compression.

Welded bars similarly tested will fail at about the same number of repetitions when the range of stress exceeds ±6½ tons per square inch.

(*b*) *Stationary test pieces* (flat plate)—

Butt welded specimens will withstand about 70 per cent of the number of repetitions which can be borne by an unwelded plate.

Lap welded plates can endure over 60 per cent of the number of repetitions necessary to fracture a lap riveted specimen.

4. *Minor Tests:*—

(*a*) Welded specimens are not capable of being bent (without fracture) over the prescribed radius to more than about 80 degrees with ¼-inch plate, reducing to some 20 degrees where the thickness is 1 inch. Unwelded material under the same conditions can be bent through 180 degrees.

(*b*) Welded plates can withstand impact with a considerable degree of success; a half-inch plate of dimensions already quoted sustained two successive blows of 4 cwt. dropped through 12 feet, giving a deflection of 12 inches on a length of about 4 feet 6 inches without any signs of fracture in the weld.

5. *Chemical and Microscopic Analysis:*—

(*a*) *Chemical analysis*—

The electrode was practically identical with mild steel, but there was a greater percentage of silicon.

The material of the weld after deposition was ascertained to be practically pure iron, the various other contents being carbon, 0.03; silicon, 0.02, phosphorus, 0.02; and manganese, 0.04 per cent respectively.

(*b*) *Microscopic examination*—

The material of the weld is practically pure iron.

The local effect of heat does not appear to largely affect the surrounding material, the structure not being much disturbed at about 1/16 of an inch from the edge of the weld. The amount of disturbance is still less in thin plates.

The weld bears little evidence, if any, of the occurrence of oxidation.

With welds made as for these experiments, *i. e.*, with flat horizontal welding, a sound junction is obtained between the plate and the welding material.

6. *Strength of Welds* (large specimens):—

(*a*) *Butt welds* have a tensile strength varying from 90 to 95 per cent of the tensile strength of the unwelded plate.

(*b*) *Lap welds.*—With full fillets on both edges the ultimate strength in tension varies from 70 to 80 per cent of that of the unwelded material.

With a full fillet on one edge and a single run of weld on the other edge the results are very little inferior to those where a full fillet is provided for both edges.

(*c*) *Riveted lap joints.*—For plates of about ½ inch in thickness, the specimens averaged about 65 to 70 per cent of the strength of the unperforated plate.

Typical examples of the statical strength of large specimens of riveted and welded joints are given in the following table:—

TREBLE RIVETED LAP JOINTS.

Thickness, inches	Diameter of rivet, inches	Breaking stress unperforated plate, lbs. per sq. in.	Strength of plain plate, lbs. per sq. in.	Percentage strength of joint
0.49	7/8	42,400	61,400	69.0
0.53	3/4	38,300	54,700	62.5
LAP WELD—FULL FILLET—BOTH EDGES				
0.514	10.02	45,300	63,600	71.0
0.73	8.76	40,330	59,600	68.0
BUTT WELD—NOT STRAPPED				
0.505	10.66	61,000	63,600	96.0
0.76	9.88	54,680	59,600	91.5

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OBSERVATIONS ON EXPERIMENTAL RESULTS.

1. *Static Elasticity.*—It will be observed that the statical tests made to determine the elasticity indicate that, in general, the combination of welded and unwelded material behaves practically homogeneously up to at least the elastic limit. Moreover, the experiments show that the process of welding is such that the stress is distributed practically uniformly over the weld and also transmitted uniformly to the adjacent plates.

The material of the weld is practically pure iron, and from the tests made on a specimen composed entirely of the deposited material of a weld it will be seen that, for a given stress, the weld stretches slightly more than mild steel. This property will enable any undue occurrence of load being transferred in a proper manner to adjacent portions of the structure.

When, however, the stress exceeds the elastic limit and is so great that the extension grows continuously without increase of load, the welded material fails sooner than mild steel. But this disadvantage is of little practical importance in shipbuilding and may be regarded as negligible in the particular problem under consideration.

2. *Dynamic Elasticity.*—In a structure such as a ship, which is exposed to variations and reversal of stresses, it is extremely important to know whether the material to be used is likely to break down rapidly under such alternations and ranges of stress as are likely to be experienced. The modified Wohler tests employed in the experiments certainly indicate, if considered solely by themselves, that whereas for a given number of alternations mild steel would withstand a range of stress of, say $\pm 10\frac{1}{2}$ tons, the welded material might be expected to fail at about $\pm 6\frac{1}{2}$ tons, a figure which is more nearly experienced in ordinary ship construction.

As already stated, the material in the weld appeared to be nearly pure iron, and experiments of repetitive stress show that wrought iron bars are likely to fail under a range of stress of perhaps ±7 to 8 tons as compared with mild steel at ±10 to 11 tons. The weld has to be deposited electrically and is subject to variations in workmanship; it would consequently be considered satisfactory if the material could withstand a range of stress of say ±6½ tons.

It would appear to be necessary to design the welded joints in such a manner that the amount of work likely to be thrown on the joint is as small as possible, and to meet such a condition a welded joint requires to be either lapped or strapped.

Consideration of the dynamic elasticity properties appears to show that in any case the welded material can experience as large a number of repetitions of stress as wrought iron could do, and it is always recognized that, although iron could not approach the tests for mild steel, it was a satisfactory material for shipbuilding purposes. Further, attention to design of details will increase the performance of the welded joint, and in addition it must not be forgotten that 5,000,000 repetitions of stress is perhaps more than equivalent to ten years' good sea service.

3. *Physical Nature and Properties.*—It has been mentioned that the welds experimented with are to be regarded as having been produced under most favorable conditions, and that throughout the experimental welds were made with the specimens horizontal and below the operator. In practice, welds will require to be made vertically and overhead as well, consequently extreme care will be required in such operations.

The physical examinations indicate that the materials of the electrode and the system of welding adopted were suitable and reliable. Moreover, there was little apparent oxidation and the material in the neighborhood of the weld was not affected to any prejudicial extent.

4. *Strength of Welds and Minor Tests.*—Broadly speaking, the tensile strength of butt welds was as great as the unwelded material, but it is considered that greater reliability of workmanship is obtained with joints which are either lapped or strapped.

It was also found that the lapped joint was practically as strong as a riveted lapped joint and would probably remain tight when subjected to more trying conditions than are necessary to disturb a riveted lap joint.

LLOYD'S RULES FOR ELECTRICALLY WELDED SHIPS.

It will be seen therefore that the arc-welded joints made by highly skilled workmen with the particular system adopted throughout the foregoing experiments (the quasi arc process, using flux-covered electrodes) proved not only reliable but in some respects superior to the usual riveted joint.

In view of the satisfactory results of these tests, the Committee of Lloyd's Register of Shipping has decided that, under certain conditions, electric arc welding may be used in the main structure of a vessel and has adopted, as a tentative measure, the following provisional rules for classification in Lloyd's Register Book of vessels electrically welded, subject to the notations "Experimental" and "Electrically Welded."

The approval of the Society will be given to any system of welding which complies with these regulations, and consideration will be given to any alternative constructional arrangements which may be submitted for approval.

TENTATIVE REGULATIONS FOR THE APPLICATION OF ELECTRIC ARC WELDING TO SHIP CONSTRUCTION.

A. System of Welding and Workmanship.

1. The system of welding proposed to be used must be approved and must comply with the regulations and tests laid down by the committee.

2. The process of manufacture of the electrodes must be such as to ensure reliability and uniformity in the finished article.

3. Specimens of the finished electrodes, together with specifications of the nature of the electrodes, must be supplied to the committee for purposes of record.

4. The committee's officers shall have access to the works where the electrodes are manufactured, and will investigate, from time to time as may be necessary, the process of manufacture to ensure that the electrodes are identical with the approved specimens.

5. Alterations from the process approved for the manufacture of electrodes shall not be made without the consent of the committee.

6. The regulations for the voltage and amperage to be used with each size of electrode, and for the size of electrode to be employed with different thicknesses of material to be joined, are to be approved by the committee.

7. The committee must be satisfied that the operators engaged are specially trained and are experienced and efficient in the use of the welding system proposed to be employed.

8. Efficient supervisors of proved ability must be provided, and the proportion of supervisors to welders must be submitted for approval.

B. Details of Construction.

9. The details of construction of the vessel and of the welds are to be submitted for approval.

10. Before welding, the surfaces to be joined must be fitted close to each other and the methods to be adopted for this purpose are to be approved.

11. All butt and edge connections are to be lapped or strapped.

12. With lapped connections the breadths of overlaps of butts and seams and the profiles of the welds are to be in accordance with the following table:—

Thickness of plate, inches	*Width of overlap seam and butt, inches*	*Throat thickness, inches*
0.40 and under	2¼	0.28
0.60 and under	2½	.38
0.80 and under	2¾	.48
1.00 and under	3	.50

Intermediate values may be obtained by direct interpolation, and for thicknesses below 0.40 the throat thickness is to be about 70 per cent of the thickness of the plate.

13. A "full weld" extends from the edge of a plate for a distance equal to the thickness of plate to be attached, and the minimum measurement from the inner edge of plate to the surface of weld is the throat thickness given in the table above.

14. A "light closing weld" is a single run of light welding worked continuously along the edge of the plate. Such a weld may, however, be interrupted where it crosses the connection of another member of the structure.

15. An "intermittent or tack weld" has short lengths of weld which are spaced three times the length of the weld from center to center of each short length of weld. Such tack welding may vary in amount of weld between a "full weld" and a "light closing weld."

16. The general character of welds is to be in accordance with the following table:—

	Inside edge	*Outside edge*
(*a*) Butts of shell, deck and inner bottom plating	F	F
(*b*) Butts of longitudinal girders and hatch coamings.....		
(*c*) Edges of shell, deck and inner bottom plating	L	F
(*d*) Butts and edges of bulkhead plating		
	Toe	*Heel*
(*e*) Frames to shell, reverse frames to frames and floors..	T	L
(*f*) Beams to decks.....		
(*g*) Longitudinal continuous angles.....		
(*h*) Side girders, bars to shell, intercostal plates, floors and inner bottom		
(*i*) Bulkhead stiffeners		

F = Full weld. L = Light weld. T = Tack weld.

17. All bars required to be watertight are to have continuous welding on both flanges with tack welding at heel of bar.

18. The welded connections of beam, frame and other brackets are to be submitted for special consideration.

19. The committee may require, when considered necessary, additional attachment beyond that specified above, and the welding of all other parts is to be to their approval.

The rules are necessarily of a tentative nature and general in character and will be modified as further experience demands. It will be observed, however, that considerable importance is attached to the system of welding, type and process of manufacture of electrode, and to the employment of specially trained operators under supervisors of proved ability.

ELCTRICALLY WELDED VESSELS.

The first vessel to be electrically welded, so far as the writer is aware, was the Dorothea M. Geary, a small launch 42 feet 0 inches by 11 feet 0 inches by 6 feet 6 inches, built by the Geary Boiler Works at Ashtabula Harbor, Ohio, in 1915. The shell, which is of 8 pounds plating, is electrically welded throughout, the joints being butted and metallic arc bare electrode used. The frames and bar keel are riveted to the shell.

This little boat has been in service in the harbor since her completion, and no signs of distress or leakage have yet been noticed in any of the welded joints.

The Richborough Barge.—The barge recently completed at Richborough on the southeast coast of England, and referred to in the daily press as "The first rivetless ship," has attracted widespread attention. The construction of this barge, which is shown in Fig. 2, Plate 150, was the sequence to a long series of successful tests on electrically welded joints carried out in England at the Admiralty dockyards and elsewhere, and will doubtless prove to be the stepping stone between the laboratory test stage and an actual full-powered ocean-going steamer yet to be built.

The barge in question is a non-propelled standard cross-channel transport barge 125 feet between perpendiculars and 16 feet beam, with a displacement of 275 tons. It differs in no way from the standard riveted type with lapped joints excepting that the seams of shell plating are arranged clinker fashion and joggled to permit of horizontal downward welding as much as possible. The hull is rectangular in section amidship with only the bilge plates curved. The shell plates are ¼ inch and 5/16 inch thick.

It was erected in the ordinary manner with service bolts spaced from 10 inches to 15 inches apart, and after the joints were welded the bolts were removed and pins driven into the holes and welded up, as it was desired to complete the structure entirely without rivets.

Five welders of considerable experience were employed on the work, using the "Quasi Arc" process with flux-covered electrodes. After a few initial difficulties had been overcome, an average speed of welding of 7 feet per hour was maintained, including overhead work which averaged from 3 to 6 feet an hour. Altogether there were from 7,000 linear feet of welding and 3,066 holes to be filled, the total cost of welding being made up as follows:—Electrodes, £178; current, £60; labor, £62, a total of £300. It is anticipated that the large proportion of this amount, represented by cost of electrodes, could be reduced by some 60 per cent with an increased output.

Careful check was kept of the total cost and the total man-hours of work involved, but a comparison with that of a similar riveted barge would be misleading, since the welded vessel was purely an experimental demonstration and no attempt was made to save material or to economize by the substitution of rivets in parts where this might have been cheaper or quicker than welding. Nevertheless it is estimated that 246 man-hours were saved over the riveted barge.

Since her completion the barge has been engaged in cross-channel service and with a full cargo of ammunition has experienced some exceptionally heavy weather, but has so far shown no signs of failure in the electrically welded joints.

Mr. A. J. Mason's Experimental Section.—With the object of trying out on full scale several methods of electric welding, Mr. Mason of the United States Shipping Board is having constructed at the Federal Shipbuilding Company's yard, Kearny, New Jersey, a 42-foot length of the full-size middle-body section of one of the standard 9,600-tons deadweight vessels, the drawings for which are shown in Plate 24.

Owing to the difficulty in securing material, some departure has been made from the regular scantlings, and ordinary tank quality steel is being used.

It is proposed to employ a variety of different methods of connection, including riveting, in the different parts, and a serious attempt will be made to apply the portable spot welder, previously referred to, both for clamping and welding.

In this work Mr. Mason is collaborating with the Welding Committee, and considerable information of a practical nature is anticipated during the erecting and welding of the structure by different systems.

The section is arranged so that on completion it may be filled with water and subjected to hydraulic and such other tests of a practical or scientific nature which may be suggested.

Designs for Welded Ships.—Two significant points to bear in mind in designing an electrically welded vessel, for the present at any rate, are, first, that our knowledge of the welded joint is still far from complete, and secondly, a welded joint has not yet been produced which is 100 per cent efficient in all respects as compared with the parent material united. With reasonable precautions it is comparatively easy to obtain a tensile strength at least equivalent to the metal united, but tension is only one of the many stresses to which such structures are subjected. It is not so easy to reproduce the same degree of ductility, the resistance to fatigue and to combined stresses of various kinds.

Another unknown factor which must not be lost sight of is the ability of a riveted vessel to adjust itself to stresses, or, as Kipling puts it, to "find" itself. The joints are made when the ship is on the ways, inanimate. When she gets afloat an entirely different set of conditions is presented, and the unbalanced internal stresses introduced during the process of bolting up and riveting are frequently intensified. However, when put into a sea-way, the repeated and alternating stresses cause her to "work," a rivet "gives" a little here, a joint "takes up" a little there, and the stresses are passed from one to the other, until the structure acts as one harmonious whole.

Just how essential is this property in a ship joint, experience with the first welded ocean-going ship alone can show.

There is no doubt that these questions will be largely if not wholly answered as a result of further study of the metallurgy and physics of welding, and with a wider practical experience of its application to the main structure of ships.

Until then, however, and in the absence of any exact method of testing the

value of the completed weld, a welded ship is at present experimental in nature and can therefore be more easily justified if designed along conservative lines.

Exception may be taken to this statement in that we have no exact method of determining the efficiency of a rivet in the hull of a riveted ship or the soundness and homogeneity of a casting or welded forging, but the answer is that the accepted methods of testing such work have been fully justified by experience and have proved that the "guesswork" involved has been within the limits of the factor of safety allowed for in the design which *per se* is the result of such experience.

In preparing the design and arrangement of material for a welded ship, it is considered desirable to keep the following practical features in view:—

1. The work has to be properly closed up for welding.
2. Overhead welding should be reduced to a minimum.
3. As much welding as possible should be done on the ground or in the shops where the material can be handled in the most favorable positions and where the discomforts and inconvenience of protective equipments are least felt.
4. In certain parts riveting may be more convenient and economical than welding.

Design for a Longitudinally Framed Electrically Welded Vessel.—Plates 25 and 26 show the midship section and shell expansion plan of a vessel designed by Mr. J. W. Isherwood on the Isherwood System of Ship Construction. The dimensions are 303 feet 0 inches B. P. by 42 feet 9 inches Mld. by 23 feet 4 inches Mld., and the deadweight carrying capacity about 3,960 tons. The arrangement of material and scantlings is much the same as in a riveted vessel of the same type, and apparently the designer has given full consideration to the practical limitations in ship construction, as well as to the limitations demanded by our present knowledge of electric welding.

The seams of side plating are arranged clinker fashion, and as many attachments as possible are welded to the shell decks and inner bottom plating before erection in order to reduce the amount of overhead welding. In fact, from a close study of the design, it will be seen that overhead welding is practically avoided altogether in the case of the strength welds.

The shell plates in this design are 84 inches in width and each plate has three longitudinals welded to it before erection, the butts of the longitudinals being welded at or near the butts of the shell plate. The numbers of shell plates and approximate total number of linear feet of "full," "light," and "tack" welds are shown on the shell plan. The system of construction lends itself to a large proportion of the total welding being done prior to erection, and in working out the details no attempt has been made towards an unreasonable elimination of bolting or riveting.

For instance, the longitudinals are attached to the shell plating by service bolts spaced 12 inches apart and are welded at the toe and heel by continuous light welds; then the bolts are removed and rivets or welded studs fitted. In other parts, where the minimum number of bolts necessary to properly tighten up the work approaches

the total number of rivets required in the riveted ship, the designer has simply added the extra rivets instead of attempting to weld.

It may be added that this vessel has been designed in general conformity with the Rules of Lloyd's Register of Shipping for electrically welded vessels.

Instructions have already been issued by the Director of Shipbuilding in Great Britain to proceed with the construction of a number of coastal vessels of about 200 feet in length after this design.

It is understood that a detailed description of the design and method of construction will be contributed to the discussion on this paper by Mr. Isherwood, therefore no further reference need be made here.

Design for Transversely Plated Vessel.—Should electric welding justify itself by actual experience and development in shipbuilding as it has done in other spheres of engineering such as locomotive, automobile and aeroplane work, the possibilities of the future in ship design awaken the liveliest imagination.

It may be found desirable and expedient to break away entirely from the present methods of erection and of arranging material for which the limitations of a riveted joint have been primarily responsible. That such an eventuality has been foreseen is evidenced by the design illustrated in Plates 156 and 157.

The design and method of erection shown in these sketches was devised by Mr. C. P. M. Jack, acting under the direction of the Welding Committee. The object of this design was not so much to demonstrate the possibility of building a welded ship as to indicate the possible saving in material, time and cost in ship construction which might result from the successful completion of the committee's work. In this design one of the principal objects aimed at was the fabrication and welding of large sections in the shops with a view to reducing overhead and field welding. The various sections prepared for erecting are shown in the perspective drawing, from which it will be seen that with the exception of the keel, center keelson, rider, bilge and sheer strakes and upper deck stringer, the vessel is plated transversely. The parts mentioned are those subjected to the maximum principal stresses and are worked fore and aft in long lengths of increased thickness, the butts being shifted and specially reinforced.

The method of erection proposed is also a radical departure from existing methods. Instead of building from the keel upwards, this vessel, it will be observed, is built from the stern forward.

A large header, mounting two electrically driven cranes and containing the stagings, pipe fitters', joiners', carpenters' and other shops, welding equipment, and foremen's offices necessary for each ship, travels along the way on tracks, as each 6-foot section is completed.

The design was adapted to standardized production and arranged so that a complete section 6 feet in length could be erected and welded at the ship during each 8-hour shift. It was intended that the shop work be done entirely by women and the field erecting and welding by men.

Welding as an Occupation for Disabled Fighters.—Apart from its importance

to the shipbuilding and engineering professions, there is an impelling reason why the subject of this paper should at least command the sympathetic attention of all interested in the future of those men who, in the defense of civilization, have sacrificed their physical fitness to return to their former means of livelihood.

In the application of electric welding to ship construction a vast field of useful and honorable employment is opened up for temporarily or permanently disabled men on their discharge from the service or hospitals. We have seen that welding is not an arduous task; a man maimed by the loss of an arm or a leg can weld as well as the physical giant. It may be that he will weld better, for such work demands the conscientious application usually found among those whose occupations are limited as a result of physical impairment. In developing the welded ship, with all its economical possibilities, we may therefore be helped not a little by the consciousness of directly assisting in the solution of this greater problem of our national industrial economics in particular and of humanity in general.

DISCUSSION.

The President:—This paper, No. 13, entitled "The Application of Electric Welding to Ship Construction," is now before you for discussion. I am very sure there should be some interesting discussion on this paper. It is a very vital question for shipbuilders to follow up, and we shall be glad to hear from any one on the floor, whether a member or not.

Mr. H. A. Hornor, *Visitor:*—Unfortunately I have not been able to peruse Mr. Cox's paper, and I have just been able to get here. But I can say, regarding the paper, without having read it, that there is nothing in it that has not been thoroughly investigated by him, because I know he has been following up closely all the work of the Welding Committee of the Emergency Fleet Corporation. He was collaborating with me for some time regarding the design which he mentions in his paper prepared by Mr. Jack, and also in looking over other designs which would make electric welding applicable to ship construction.

Without wasting your time or adding anything to his paper, I would like to have your attention rivetted to one point in regard to this application. In all of the investigations that have been made regarding the process, it was discovered, and very early, that this particular process was introduced into the field, and it has been applied by steel men up to the present time.

Those of us who have had occasion to look up other processes in engineering have discovered, naturally, that a certain amount of work and time has to be devoted in transferring such a process from the field into higher and greater things, and also to make it practicable for the purposes intended. This work, or course, under the stress of war has been done intensively, and possibly for that reason there are certain engineers who are in doubt as regards its applicability, but I want to call your attention to the fact that intensive work has been done in moving this particular application from the field to the higher services, and the crux of the situation rests in the operator.

The field man was perfectly sincere and perfectly conscientious in what he called making a weld. All the metallurgical investigations, all the scientific research were concentrated on what was in the weld that the man had made, and it was soon discovered that, if you take a man, and especially a man who was not of the order of the laborer, a man of a higher order, a man who is accustomed to use his brain and use it with rapidity, because the arc is a very "rapid fire" proposition—if you take a man of that type and start to train him and to inject into his consciousness a sense of responsibility of the craftsman, immediate improved results appear.

Now, strange to say, the research men are going backward on that very proposition. They are now making negative trials, and I had a request just before leaving my office to make a weld which was bad—they are finding difficulty now in turning around and making a bad weld in order to investigate why the weld is bad, and also in their endeavor to find some non-destructive method of testing the weld.

I think that every one of the shipbuilders, every one of the naval architects, and every one of the marine engineers may feel absolutely no hesitancy to-day in applying the process safely to such a serious thing as a ship. I realize, as you all do, that a ship is a very serious matter, involving a great deal of money to build and a great deal of money in the carriage of cargo and carriage of life, and I would be the last man in the world to say to you gentlemen to-day, and to say it freely and boldly, that the method is perfectly safe to use to-day, if you observe one thing and treat that one thing conscientiously, and that is the craftsman you put on the job.

If you have craftsmen who are determined in their own minds to be something more than craftsmen, and you will go back to what your Society stands for, the art of shipbuilding, and make them believe that shipbuilding is an art, and in using that electrode they are doing nothing more or less than the painter in handling his brush, and that in the steel structure they have nothing but what the sculptor has in his marble, and you gather around them a central mind to guide that work and a number of men to aid him, you will undoubtedly carve a monument in steel with the arc and with the electrode.

Mr. Spencer Miller, *Member of Council:*—I would like to ask a question—how many artisans or craftsmen would be required to electrically weld a ship to be launched as rapidly as is now done with the rivetted ship?

Mr. H. Jasper Cox:—That would largely depend on the size of the ship. In this paper you will find some data on the subject of welding, which you can apply against the speed of rivetting per lineal foot of seam or joint.

Mr. H. M. Hobart, *Visitor:*—I wish on behalf of the Welding Research Sub-Committee to express their hearty appreciation of the splendid co-operation of Lloyd's Register of Shipping and the American Bureau of Shipping. Lloyd's Register of Shipping, which was represented on the committee by the author of this paper, helped us out at every point from their immense fund of technical information.

Prof. C. A. Adams, the chairman of the Welding Committee, was particularly desirous I should describe the research work which has been done by the Welding Research Sub-Committee. We recognize that Britain made a splendid contribution to the advances which have been made in the art of electric welding, especially in the art of electric welding as applied to shipbuilding. But we feel that from the point to which they brought the art, our work during

the last year, and perhaps more noticeably during the last six months, has led us to have a more definite and positive knowledge of the conditions essential to sound welding than has been heretofore available.

We have been heartily encouraged by the Emergency Fleet Corporation in making these researches, and we believe that we already have a rich return for the outlay and that still further lessons of the greatest value will be learned by us in the very near future.

Even the briefest outline of the extensive and important work which we have in hand would occupy too much time. Consequently, I have concluded to deal chiefly with a single subject, namely, with the results of a series of tests of double-Vee welds of half-inch ship plate of the following composition:—Carbon, 0.25; manganese, 0.46; silicon, 0.034; sulphur, 0.03; phosphorus, 0.04.

Welds of the dimensions shown on the chart (8 inches long, 45-degree, double-Vee welds) were made at a dozen different places in the presence of Messrs. Wirt and Jones of our committee. At each place the operator employed whatever conditions were considered most suitable. All sorts and sizes of electrodes, including bare and covered types, were used. While in the majority of cases direct current was employed, alternating current welding is also well represented by quite a number of welds made at different places. Some alternating current welds were made with 60 cycles and some with 25 cycles. If Mr. Cox's paper had been read a fortnight later, we could have contributed the results of some 30 per cent more such welds, the tests of which have not yet been completed. It is, however, reasonably certain that the results from these remaining samples could not materially alter the conclusions. I wish to make the most careful reservations of entire right to amend our conclusions in any way when we have had time to further check and digest our work. In fact, the material which I am now placing before you has been arranged in so short a space of time that it has been impracticable for me to submit it to the Welding Research Sub-Committee for any revision or endorsement of the statements which I shall make. Consequently, and with much concern at the responsibility, I must put them forward as merely my own opinions.

One remarkable observation relates to the utter absence of any agreement amongst welding specialists as to the preferable electrode material and as to the conditions as regards system of supply and the conditions as regards current and voltage for obtaining the best results.

My first step was to divide the results into two groups, namely, welds made with bare electrodes and welds made with covered electrodes, with a view to comparing their mechanical characteristics as regards bending strength, torsion strength, tensile strength and per cent elongation at fracture. This attempt led me nowhere; any difference in the average results were too small to be admitted to possess significance.

This was also the case when I attempted to contrast D. C. and A. C. welds. I found no notable difference in the mechanical characteristics.

But, on studying the influence of the current employed in making the weld, there at once became apparent a very great improvement in all the mechanical characteristics with increasing current. The four diagrams in the upper row of the chart (Plate 158) speak for themselves.

Black squares ■ relate to A. C. welds made with coated electrodes.
White squares □ relate to D. C. welds made with coated electrodes.
Black circles ● relate to A. C. welds made with bare electrodes.
White circles ○ relate to D. C. welds made with bare electrodes.

It will be observed that D. C. and A. C. results are quite evenly distributed above and below the resultant curve, as is also the case with results with bare and covered electrodes. But the beneficial effects of employing heavy current are distinctly evident with respect to all the four mechanical characteristics on which the tests were made. Considering, for a minute, the chart showing the relation between the tensile strength and welding current, we see that if the weld is made with some 90 amperes, the most probable value for the tensile strength is only some 43,000 pounds per square inch, whereas if the weld is made with 180 amperes, the most probable value of the tensile strength of the resulting weld will be nearly 50 per cent greater, namely, well above 60,000 pounds per square inch. Similar ratios of importance hold with respect to the bending test, torsion test, and the per cent elongation at fracture.

The following schedule shows the distribution of the total of twenty welds in different classes:

Bare (12)	Direct current (9) plotted as white circles. Alternating current (3) plotted as black circles.
Covered (8)	Direct current (2) plotted as white squares. Alternating current (6) plotted as black squares.

The twenty observations were divided into three groups: "A" for eight welds made with 150 to 175 amperes; "B" for six welds made with 105 to 145 amperes; "C" for six welds made with 83 to 94 amperes.

As already stated, there was no attempt on the part of the committee to suggest to the proprietors or users of systems or electrodes, the current to be used, or any other conditions, and it is fair to conclude that in each case the conditions employed were believed by the makers of the weld, or by the operators, to be the most suitable conditions.

The average values obtained for Groups "A," "B," and "C" are shown in the following table:—

	A	B	C	Ratio of A to C
Current	158	123	89	1.78
Ult. strength (lbs. per square inch)	59,000	50,000	46,000	1.28
Per cent elongation in 2 inches	8.9	6.2	5.0	1.78
Torsion-torque ratio	0.86	0.75	0.67	1.28
Bending angles in degrees	54	45	32	1.68

I conclude that the reason for the wide use of 100 amperes and less, for a weld of these proportions, is that there are more operators who can make superficially good-looking welds with such a current than there are operators who can manage currents of twice their value.

It is very important to note that, with sufficient skill on the part of the operator, not only will the high-current weld be made more quickly, but it will also have much better mechanical characteristics. In so far as these various conclusions are correct, they emphasize the importance of concentrating on the development of automatic welding machinery, since it is reasonable to assume that, with such machinery, higher speeds can be obtained, which, as we have seen from these results, are associated with higher currents which in their turn are associated with better welds.

A few months ago, the Welding Research Sub-Committee sent out questionnaires by means of which it obtained statements of the current employed at that time by various concerns for work of various dimensions and shapes. In the following table are given the values employed by five different undertakings for welds equivalent to the welds in this series of tests, and in the last line are given the values indicated by this study of the results from the Wirt-Jones tests.

CURRENT FOR WELDING HALF-INCH THICK SHIP PLATE.

	Current recommended (in amperes).	*Kind of electrodes.*
British practice	75 to 120	Flux-covered
Atchison-Topeka and Santa Fe Railroad	115 to 125	Bare
New York Central R. R.	110 to 150	Bare
Chicago, Rock Island and Pacific Railroad	80 to 135	Bare
Indications from some advance results from the Wirt-Jones tests, at least probably	175 to 200	Bare and covered

It was interesting to note, from the data obtained from the 20 welds of the Wirt-Jones series, that the operators who employed the largest current did not always employ electrodes of the largest cross-section. In other words, no consistent relation was observed between the current employed and the size of the electrodes, different operators employing different current densities. In fact the current densities employed for these tests ranged all the way from 6,000 amperes per square inch up to 14,000 amperes per square inch. In Mr. Cox's paper is given a table of recommended sizes of electrodes for various currents for covered electrodes. I have analyzed these values and found that the recommended current densities range in most cases from 4,000 up to but little over 6,000 amperes per square inch. For covered electrodes as employed in England, the use of lower-current densities than are necessary for bare electrodes is claimed as an advantage. I doubt whether they are right on this point, and I am also inclined to believe that they use too large electrodes. Although they obtain good welds, I doubt if they are obtaining as good welds with the use of these low currents and low-current densities as could be obtained if they should redesign their electrodes so as to maintain an equal rate of consumption of the flux covering and of the core when working with the high-current densities. With an American design of covered electrode represented in the curves by four points, high-current densities are employed and with decided advantage, so far as relates to the mechanical characteristics of these four welds.

The four lower curves of the chart represent an attempt to ascertain whether any conclusions could be deduced with reference to the effect of the current density on the mechanical characteristics of the weld. I call the attempt by no means successful; nevertheless, a great deal of interest can be learned by inspection of these curves. Thus we observe that the current densities range, as already mentioned, from 6,000 amperes per square inch upwards, whereas British practice is confined to value below 6,000 amperes per square inch. Obviously, if for making a given weld, with a given current, an operator uses an electrode of half the cross-section employed by another operator, the electrodes will burn away at twice as great a rate. In view of the present practice of employing straight, short lengths of electrodes, this would mean as frequent renewal of electrode and a great loss of time in putting new electrodes in the holder. Such considerations have probably contributed to the use of lower-current densities

than could otherwise have been employed to advantage. It is hoped that the advent of automatic welding machines, feeding wire from reels at a rapid rate, will permit using high currents and high current densities, and of obtaining the better mechanical characteristics accompanying these higher values.

The following table sets forth the average; for the three groups employing (A) highest; (B) intermediate; and (C) lowest current densities:—

	A	B	C	Ratio of A to C
Current density (in amperes per square inch)	10,800	7,400	6,450	1.67
Ult. strength (in pounds per square inch)	57,000	50,000	48,000	1.17
Per cent elongation in 2 inches	8.8	5.8	6.7	1.31
Torsion-torque ratio	0.81	0.78	0.71	1.14
Bending angle in degrees	49	47	36	1.36

The reason underlying the extremely definite indications as regards the quality of the welds when studied as a function of the welding current and the relative vagueness of the indications when an attempt is made to study the influence of the current density, is that the former, as regards its influence, is the dominating variable, while the latter is on a par with many other minor variables and judgment as regards the influence of the current density in the electrode, should be reserved until suitable research work is completed in which, with constant current, different cross-sections of electrodes are employed.

SIDE PLATING AND INTERNAL WORK.

Full welds.—Outside edges of shell overlaps. Butts of shell plates and longitudinals. Connection of transverse plates to shell clips. Connection of transverse to inner bottom plating.

Light welds.—Inside edges of shell overlaps.

DECK AND INTERNAL WORK.

Full welds.—Seams of deck plating. Butts of deck plating and longitudinals. Heel of gunwale bar. Connection of beam to transverse.

Light welds.—Connection of transverse beams plates to clips already on deck. Pillar and detail work.

The same remarks apply in regard to the filling of service holes.

In conclusion I would like to add that it will give me pleasure to add details of the various parts showing the kind of weld and the service holes required, so, if the Society thinks fit, they can be added to Mr. Cox's paper.

Lieutenant Commander H. G. Knox, *Member:*—I received a copy of this very interesting paper late last night, and only had an opportunity to look it over hurriedly on the train this morning.

It appears to me that one of the conditions of the art of welding to-day is in effect that arc

welding grew up from the shop rather than in the draughting room. The value of repair work done by arc welding was clearly demonstrated to the country in the case of the repairs to the cylinders of the German ships, of which we have heard a great deal. At Norfolk we are at the present time welding a great big cast-iron cylinder from the steamer Rondo, which is probably a bigger job than any of the applications in connection with the German ships. When we want to repair an article in the navy yard or in the shipyard we go to the welder for advice and not to the draughting room. When we need new work, obviously we go to the draughting room and not to the welder. The draughting room is waking up to the fact that it is behind the times in arc welding.

The drawings for new construction work are largely based on the experience of years and on classification rules, specifications, and other forms of standard practice, but in welding we still have all that ahead of us, and for that reason, also, we have nothing as yet to go by.

The development of welding is gradually leading up to a new profession, that of Welding Engineer. The designation "engineer" is much overworked, it is true, but we are at present dependent on the mechanic and welder and are gradually educating the engineer, who will then form a combination of practical men and theoretical men. When this is accomplished we will have a great stimulus in the art of welding.

The use of resistance welding referred to by Mr. Cox, is, I think, primarily of use for repeat production work rather than job work or in general construction work on the hull structure. The use of resistance welding, known generally as spot welding, ridge welding, or line welding, is mainly a shop method and always will be unless the tests now under way by Mr. Mason demonstrate the possibility of getting a large spot welder which can be used in the field and supported by a crane for erecting very heavy plate work. In other words, the resistance welder is a machine to which the work will be taken, while the portability of the arc renders it a field device which can be readily taken to the work.

The sheet metal articles used in shipyards or navy yards, while perhaps not often considered by naval architects, represent a tremendous output, and probably all of the plate that is handled in ventilator work, and in many bulkheads and lighter structures in ships, can be done by spot welding in one form or another, and that applies to black plate and a galvanized plate from 5 to 7.5 pounds. That is particularly true with reference to battleships, and also, to some extent, in merchant ships.

At the Norfolk Navy Yard we recently installed a butt welder of 1¼ inch diameter capacity. I believe there was a machine there some years ago of similar type, but the records were lost, and we are considering this as a new machine. In the few months it has been in use it has more than paid for itself. We can weld rings from 1 to 1¼-inch diameter wire and such things as angle collars and angle rings for ventilators, within the capacity of the machine. One thing pertaining indirectly to the ship construction is the welding of high-speed tips on nickel steel shanks and we use practically no other kind of tools in our shops. All of the welding is done on this machine.

We also salvage all broken drills, which is of interest to shipbuilders, and this machine recently welded a broken 2.5-inch high-speed drill. After the weld was made the drill was driven until the drill-press stalled, showing the drill was quite strong enough.

Another form of the application of electricity in shipbuilding not mentioned by Mr. Cox is the electric heating of rivets, and, while it is not within the scope of this paper, that form of energy in obtaining heat for rivets is being extensively used. One form of machine heats the

rivets in multiple, and another heats four in series. This work is done very successfully and replaces the usual forge.

Another adaptation of electrical energy is in the heating of rivets inserted in plates. For this method is claimed not only rapidity of operation but also annealing of the plate in the vicinity of the hole, due to the heating in place.

Mr. Cox refers only slightly to the use of the carbon arc, and that is probably because he has considered here, again, welding of the ship structure proper. On the lighter work that goes into a ship (the sheet metal work) there is a vast field for the carbon arc, and this is particularly true of the carbon arc mechanically driven.

Although the hand-operated carbon and metal electrodes have been used exclusively up to the present time, the development of the mechanically driven electrode is now making rapid strides, it is doing practical work of a high order, and there is every reason to believe that it will supplant hand welding in many places. Mr. Hobert's remarks on the advantages of high-current densities and high-current values will tend to accelerate that progress.

In shipbuilding, considering the structure as a whole, the metallic electrode will, of course, be the principal means used, whether bare, coated, covered, or composite. By composite I mean a steel electrode with some form of core. The Research Sub-Committee of the main Welding Committee is now engaged on the development of steel electrode wires with cores applied somewhat after the fashion of electric light carbons.

A reference is made in the paper to the tests of larger sized models. I did not arrive in time to see the moving pictures, but I believe a picture was shown of Mr. Wagner's 12-foot cubical tank at Pittsfield, which has been welded and tested with repeated bending tests. At Norfolk there is a similar tank almost finished, which is to be subjected to similar tests. The welds in the Norfolk tank are different, but its design is practically the same, though it is of somewhat smaller size.

We are also building at Norfolk a battle-towing target, the design of which some of you may know, but for the benefit of the others I will say it is a target carrying a large screen, towed behind battleships, and used in their gunnery practice at sea. Among other parts it has a steel vertical box keel 100 feet long by 16 feet deep, made up of half-inch plate. The two vertical sides are braced 4 feet apart, with cross frames or floors. The welding of this target is under way and we would be glad to have any one interested call and see it.

Two days ago we had one of the first chilly days at Norfolk, and a little after 7 o'clock the first gang got out and began chipping out a bad spot in a weld. Suddenly a whole butt between two of these plates went off like a gun. The cause of the break was the contraction of an improperly welded strapped butt joint. The welders had first welded the fillet on each edge of the strap and then filled in the bevel between the plates being joined. They had thus introduced some molecular strains in the filler metal, so that the cold weather, coupled with the hammering in the vicinity, caused the seam 6 feet long to let go. It was, nevertheless, a very useful lesson and we were not surprised at the break. We now understand how to weld strapped butts.

When the Jupiter was put into use, there were two questions often asked: First, whether there was not some danger from the voltage (2,300 volts); and, second, whether dampness would not affect the integrity of the insulation. I was questioned many times about the Jupiter and these were the two principal questions which were put. Similarly in arc welding, the questions generally asked are the ability of the arc weld to resist vibration, its ductility in case of collision, and its ability to resist corrosion.

Tests on the resistance to vibration made both in England and, in this country, at the Bureau of Standards indicate that the arc-welded joint, properly made, is entirely able to stand repeated stress to almost the same extent as the unwelded plate, provided the working stress in the weld is limited to about 60 per cent of the fiber stress developed in the unwelded plate. Vibrations of over 5,000,000 have been obtained by repeated stress on Upton-Lewis machines.

As to ductility, a valuable point in ship design, that is being investigated by the Welding Committee in this country, and the report of Lloyd's in this country, and the British Admiralty in England, both throw considerable light on this factor. Considerable difficulty is experienced in assuring ductility.

The question of corrosion has been made the subject of study both in England and in the United States, both natural corrosion in sea water and accelerated corrosion in dilute acids. At Norfolk tests were made on various electrodes with different currents and current densities, and the information we have acquired to date, including examination of specimens attached to the bottom of ships in service, is entirely favorable to the welded joint. There seems to be no reason to doubt the ability of the welded joint to withstand corrosion in an entirely satisfactory manner.

Most people accept the principal claims for arc welding—low cost, time saving, reduction in weight, strength and inherent water and oil tightness—and it is only the two or three questions to which I have just referred that cause the comment.

There are, however, certain disadvantages inherent to arc welding. I have noted four here. The first is the difficulty of supervision and inspection; that presents one of the most serious difficulties and is being investigated on all sides. The break in the towing targets at Norfolk just referred to was entirely due to poor supervision, because we knew it was the wrong way to weld a strapped butt, and yet that particular job was welded in this manner. We are getting samples from other butts, welded in the same incorrect order, and will subject them to tensile tests.

The second objection to arc welding is interference to other workers. The arc is very harmful to the eyes, so that it is necessary to afford protection to others in the vicinity. That is well taken care of by screens when working on horizontal surfaces, but presents more difficulties when the men are working up and down the sides of ships. We are working on designs of screens for that purpose, but, having relatively little of this welding to do, the investigation has not proceeded very far.

A third objection to arc welding is the distortion due to heat developed by the arc, a serious difficulty, and we have already had trouble in the battle-towing target due to that cause. That was first encountered in bolting up some of the earlier work, and we thought we knew how to handle it, but it has continued to give trouble. Experience will soon indicate means for obviating this difficulty.

The fourth objection to arc welding is the difficulty of opening up for repairs a welded ship or other welded structure. No doubt that will be difficult. I find that the electrical engineers who design motors and generators, which we in the navy yards have later to repair, do not think much about the way to get their machines apart. They are solidly put together, and the poor devil who has to take them apart to get at an inner winding has his troubles. We will, of course, have troubles in the case of the welded ship, except that the oxy-acetylene cutting torch will enable us to cut a hole so neat that the plate removed can be welded in again.

The immediate development of the art would seem to require us to push vigorously the

all-welded ship. People familiar with the present state of the art agree that the time is ripe for the project.

Lloyd's Register, American Bureau of Shipping and other classification societies have already authorized the use in this country of an enormous amount of arc welding. There are thousands of authorized fittings on which arc welding can profitably be used by shipyards to-day. Many of the unimportant structural members of a ship can be welded, and it seems a shame, in some ways, that welding has not been further used in the shipyards. The shipyards have, of course, been working at war-time speed, and it is inadvisable to interrupt the orderly course of their work. On the other hand, a saving of time and money by the use of arc welding, where already authorized, and where no chances are taken in its use, would certainly seem to warrant its immediate introduction.

Its further introduction is limited by apparatus, perhaps, and the training of welders, but above all by the training of the engineers I first spoke of. While we can train welders in six weeks or three months, we cannot train the engineers in any such time, and the greatest problem confronting the shipbuilders to-day is the training of the men higher up.

Constructor Commander S. V. Goodall, Royal Navy, *Member:*—Mr. Cox is to be congratulated on his paper; its interest is shown by the length of the discussion. I think, too, that the registration societies, especially Lloyd's, are to be congratulated on their progressive attitude towards the application of electric welding to ship construction.

I would like to emphasize more particularly the remarks on page 212 of this paper and to say that electric welding is already established as a valuable accessory to shipbuilding in the manner described therein. In Great Britain electric welding has been found to be invaluable during the war. Ships that ordinarily would have been out of service for many months have been repaired in a few days and have returned to the fleet. I have noticed with regret, in many of the shipyards I have visited in this country, that welding as an accessory to shipbuilding has not been adopted as extensively as it could be. I am sure that shipbuilders would find that a gain in time and cost would result from a greater application of electric welding.

With regard to the electrically welded ship, the policy of the British Admiralty, as the result of some experience, is to proceed with caution. The Richborough Barge referred to in this paper has done useful service successfully, but the plating of that vessel is comparatively thin, and it is with thicker plating that difficulties have been experienced.

The heaviest work so far done has been in the construction of what I might call a "false side," which has been added to several battleships as additional precaution against torpedo attack. The added structure was similar to that of an ordinary ship's side, the plating was generally about one-half inch thick, and arc welding was employed to a considerable extent.

These ships have been carefully watched on service, and the troubles that have arisen have not been greater than might ordinarily be expected with such a drastic change in procedure. However, there have been troubles, and it is advisable that they should be known and analyzed in order that, both in Great Britain and America, we may benefit by them. In that respect, I should like to say, in passing, that the co-operation which has existed between this country and Great Britain has been invaluable; in a letter only recently received from England my chief expressed his appreciation of the mutual benefits resulting from an interchange of information on this subject, and I trust that after the war such co-operation will be continued.

As the result of experience with work such as I have described, the Admiralty has concluded that, although it is perfectly easy for a skilled welder to make, for test, welded joints that will give the satisfactory results that have been referred to in this paper and discussion, yet in building a ship there are difficulties on account of the complicated nature of the structure and its rigidity, that result in very different conditions to those attending the welding of two simple plates. The system of assembly for welding so far adopted in Great Britain is that referred to in this paper as the rigid system. Under that system lapped joints have been successfully made and have been satisfactory on service. Particular care must be paid to arranging the joints so that the main part of the welding is downwards, not upwards. Difficulty has, however, been experienced under that system with butt welds, particularly with butt welds of thick plates. Such difficulty had previously been experienced with heavy test pieces; accordingly it was originally decided to limit butt welding to plates of 25 pounds and under. Now, in the light of experience on service, the Admiralty has decided to limit butt welding to 15 pounds and under, where strength is important, until further experience has been obtained, when it is expected that it will be possible to go to thicker plates.

Mr. Joseph W. Isherwood, *Member*:—Was that a horizontal weld or a perpendicular weld?

Commander Goodall:—That was a vertical weld. Reviewing the situation, the experience obtained with the work I have described has led the Admiralty to lay down, in regard to warships, the principle that electric welding for structural work, subjected to high stresses, may only be adopted where it is possible to test the work in a manner representing the tests to which the joints will be subjected on service.

Mr. Charles P. M. Jack, *Member* (Communicated):—The application of welding to shipbuilding is of the utmost interest and importance, and the able paper under discussion should do much to show the possibilities and clarify some of the mysteries connected with the art.

The special reference to a design prepared by me under directions of the Design Committee of the Emergency Fleet Corporation, Welding Committee, seems to call for some explanatory remarks.

The design was prepared primarily to show advantages which might be looked for in ship construction, due to the introduction of a radical departure from existing methods of construction by the introduction of joints of high efficiency, being assured by the Electric Welding Committee that the following joint efficiencies could safely be taken:—

		Efficiency in tension.
(1)	Joints of fore and aft plating	100%
(2)	Joints of transverse plating overhead welding	80%
(3)	Joints of transverse plating vertical welding	85%
(4)	Joints of transverse plating flat welding	90%
(5)	All joints in compression 100% efficiency.	

It was decided to abandon the customary shift of butts in shell plating and to run all the plating transversely, except the major longitudinal strength members; namely, the shear strake, deck stringer plates, bilge strake and keel. Scantlings of these longitudinal strength

members were increased to permit of them taking a greater part of the stresses than is at present customary. The scantlings of the transverse plates were slightly reduced. Transverse plating, including all connections thereto, frames, floors, deck beams, etc., were designed so that they could be prepared in the shop and delivered to the ship in complete units, ready for connection to the adjoining plating.

In a 6-foot length (6 feet being the width of plate suggested) there are six transverse parts of the hull to be set in position: namely, port and starboard outer and inner bottoms, including floors; port and starboard side plating, including frames; upper deck; lower deck, including beams. The longitudinals were also designed to be lifted in large sections so that in, say, a 30-foot length there would be 10 sections to place in position; namely, 2 sheer strakes, 4 stringer plates, 2 bilge plates, 1 center girder and keel, 1 rider plate.

The method of construction proposed consisted of a header to travel on rail tracks, placed lengthwise of the slip, the construction to commence from the after end and to progress in specific stages, regulated by the time required for entirely completing one 6-foot section of the hull. On the header being moved back the six transverse lifts are to be placed in position by the cranes provided for the purpose on the top of the header. Clamping and securing devices provided on the header are then applied to secure and regulate the sections in position.

The welders, who operated on staging or platforms carried on the header, are provided with the necessary current by apparatus placed in the header. The necessary stores, toolshops, etc., are also located in the header.

The object of this method of construction is:—

1. To enable a large part of the work to be prepared in the shop.
2. To enable the assembling in the ship to be done with a small number of pieces.
3. To enable the work to be laid off in such a way that each day will have its specific task and that the entire hull construction gang will be under the immediate eye of the foreman in charge; the header only moving backwards upon the section being, as far as the hull is concerned, completed.
4. To enable the fitting of machinery, equipment, etc., to proceed at the same time as the hull construction.

As soon as the few after sections are completed the engineers could get ahead with the fitting of the stern tube, shafting, propeller, etc., and with the fitting of steering gear, winches, etc. When the hull construction has been completed up to the forward end of the engine-room the engines can be placed in position, and in a similar manner, when the construction is completed up to the forward end of the boiler-room, the boilers can be placed in position. The work of installing auxiliaries and connecting up the machinery can proceed and be completed by the time the hull construction has reached the stem.

In like manner, carpenters, joiners, pipe-fitters, etc., can proceed with their work, the object being to launch the vessel, complete in every respect, immediately the last rivet is driven in the stem.

The most radical suggestion in this design is, of course, the abandoning of shift of butts. The practice of shifting butts seems to be a relic of old wooden ship construction, where the butts had no efficiency and consequently could not be placed all in one line.

In ordinary bridge construction the major stresses are taken by upper and lower strength members, connected with diagonal or other bracing. In a like manner it would be possible to design a ship with sufficient strength in the bilge strakes, keel and two upper cor-

ners to withstand all the longitudinal stresses and making suitable connections between these members with diagonal bracing.

We have, however, in a ship also to consider water pressure, which means plating. A ship might be designed with transverse joints made sufficiently flexible in a longitudinal direction to assure the entire longitudinal stresses being borne by the strength members. Such a ship, however, would naturally require increased material. The design proposed contemplates stressing this intermediate transverse plating to an amount proportionate to the joint efficiency.

I have for some years considered the possibility of building riveted ships along the lines proposed in this welded-ship design, and find it possible to design such a ship with riveted connections without increasing the hull weight. In a welded-ship design we have been able to show a substantial saving in weight, approaching 20 per cent of the total hull steel in a 9,000-ton dead-weight 'tween deck cargo vessel of the ordinary three-island type.

The main savings in the design due to welding consist of:—

1. Reduction in overlaps by using butt connections.
2. Reduction in angle flanges due to connecting the web of frame, beams, etc., to the plating at right angles by welding.
3. The saving of rivet heads.
4. Reduction in scantlings due to increased joint efficiency.

The efficiency of the joints is by far the most important factor and upon this depends the future of the welded ship. It is, therefore, most encouraging to know of the excellent work being done by the members of the Emergency Fleet Corporation, Electric Welding Committee, and by Lloyd's Committee, which encourages the prediction that in the near future welding in some form will be the connecting medium used in ship construction.

Mr. W. L. Merrill, *Visitor* (Communicated):—In connection with Mr. Cox's very instructive paper on welding and training of welders, I wish to emphasize the importance of training welders not only for ship work, but for any other class of arc welding.

There have been in the past too many failures of the arc-welding process in the industrial field, due to the supposition that the welding apparatus and electrodes did the welding. This is far from true. In the enthusiasm of manufacturers to sell welding apparatus too little attention has been paid, in many cases, to the importance of the operator, and even now I personally could not say whether successful arc welding is a trade or an art. Whichever it is, the man must acquire proficiency in doing the work if his work is to be successful. With the older trades no one would think of taking a blacksmith—that is, a good blacksmith—and give him a set of high-grade wood-working tools and expect him to do successful cabinet work at the start. Should such a condition exist, what is more natural than that at this first few trials he should make a failure and tell his employer that it was due to the tools with which he had been supplied. This is absolutely analogous of what happens in many cases in arc welding. I would say that, briefly, the fundamental requirements for a successful arc welder would be, first comparative youth. This is necessary on account of the steadiness which he must develop with his welding hand, and, while men past middle age have become good welders, it takes a great deal longer to require the "feel" and the steadiness of the muscles, and the operator is very apt to become discouraged. Second, a man should preferably have some previous experience in metal work, be it as blacksmith, in boiler shop, machine shop or what not. Third, he should have patience.

The art or trade of welding is possibly divided into two general classifications—that is, reproduction work of some simple operation, such, for example, as a flue welder in a boiler shop. The other classification is what is known as a general all-round welder who is competent to do any work from filling blow-holes in castings to thin metal overhead welding. Under the first classification it is rather easy for a man to become expert, and he need not be of as high a type of workman as the second class. Many women at the present time are very successful welders on reproduction work, although at present I do not know of any who might be termed general all-round welders, but assume that some will be developed in the future. The all-round welder, in order to be successful, must have a thorough, rigid training, starting with the simplest of all welding operations, striking the arc and laying down metal on a flat surface; from that to joining pieces, filling blow-holes, building up parts, to vertical weld, horizontal weld, overhead welding, welding in difficult places with very long electrode, and he must become proficient in all of these exercises before he is competent to do important productive work. To become an all-round welder he must develop that peculiar sense of intuition which satisfies him that, as his work progresses, he knows he is making a good weld.

It must be borne in mind that the mask which it is necessary to wear obstructs his vision to a great extent. One of the final tests which a proficient welder can pass is making a good weld blindfolded. I do not say that this is necessary, but simply state the fact that a number of excellent all-round welders who have come under my observation are able to do it, as they say, by the feel and sound.

In conclusion I would urge on any member who is contemplating the installation of the arc-welding proposition, or who has an installation he feels he is not getting the best results from, that the first thing he should do is to pick the necessary number of clean, energetic young men, and make use of one of the many training schools for welders. I would also urge that in doing this he be not discouraged if it takes two months or more to make his man proficient. After all when you consider that this is a trade or an art which, when properly applied, is a great benefit as a time saver and a cost reducer, even six months would not be unreasonable to expect a man to take to become proficient, although two or three months should be ample.

I wish you also to bear in mind that any one can burn up electrodes, that it is no trick whatever to deposit metal, but that to make welds which can be relied upon is an accomplishment which must be considered on a par with many other skilled trades.

W. E. Symons, *Visitor* (Communicated:—Owing to the late receipt of the advance copy of paper on electric welding and the fact that a previous engagement prevents my attendance at the meeting, I have only been able to make a few hurried remarks. The paper is a valuable addition to engineering literature and will be of much assistance to the practical mechanic.

I fully agree with the author as to testing welds as outlined on pages 205, 210 and 211, and also as a firm believer in the rigid system of joining plates, and that the system of depositing metal outlined by Naval Constructor H. G. Knox, and recommended by the author, if followed, will insure against defective welds and welding.

I am in full accord with Lloyd's policy in their attitude toward electric welding on ships and ship machinery, and their requirements as to high-grade supervision and competent welders on the work, referred to on pages 213, 214 and 220. The suggestion to use disabled soldiers and women on this work is a good one.

THE PRESIDENT:—Is there any further discussion on this paper? Do you wish to add anything further, Mr. Cox?

MR. COX:—There is nothing I wish to say.

THE PRESIDENT:—The next paper is No. 14, entitled "Hog Island, The Greatest Shipyard in the World," by Mr. W. H. Blood, Jr., Visitor.

MR. W. H. BLOOD, JR.:—Mr. President and gentlemen, the hour is late and I know some of you want to go to Hog Island. I will simply show this.

Mr. Blood then showed two views of Hog Island—one before, and one after the shipbuilding plant was erected.

HOG ISLAND, THE GREATEST SHIPYARD IN THE WORLD.

By W. H. Blood, Jr., Esq., Visitor.

[Read at the twenty-sixth general meeting of the Society of Naval Architects and Marine Engineers, held in Philadelphia, November 14 and 15, 1918.]

To fully comprehend the development, plan and scope of the Hog Island shipyard, one must know the conditions which called for it and the steps which led up to its creation.

On May 7, 1915, the Lusitania was torpedoed and shortly after, during the same year, other British steamers, the Arabic, Ancona and the Persia, to say nothing of numerous smaller vessels, belonging to the allied nations, were sent to the bottom. Many neutral steamers, regardless of nationality or destination, were also sunk, until the total tonnage destroyed in 1915, according to British Admiralty reports, ran up to 1,800,000 deadweight tons. The record of sinkings for 1916 was over 2,500,000 deadweight tons, and it looked at that time as if Germany might continue to keep up, or possibly increase, this ratio. It was evident that the world's supply of ships was fast diminishing and there arose an urgent demand that the United States start at once the building of a merchant marine, a thing long talked of but never realized.

Congress, recognizing that such a condition existed, on September 7, 1916, passed an act "To establish a United States Shipping Board for the purpose of encouraging, developing, and creating a naval auxiliary and naval reserve and a merchant marine to meet the requirements of the commerce of the United States with its Territories and possessions and with foreign countries; to regulate carriers by water engaged in the foreign and interstate commerce of the United States; and for other purposes."

Under the Emergency Shipping Fund Provision of the Urgent Deficiencies Appropriation Act, approved June 30, 1917, the President was, among other things, empowered "to place an order with any person for such ships or material as the necessities of the Government, * * * may require during the period of the war and which are of the nature, kind, and quantity usually produced or capable of being produced by such person." The President was also authorized to exercise the power granted to him and to expend the money appropriated, through such agencies as he might determine. This power was delegated to the United States Shipping Board Emergency Fleet Corporation by executive order and thus a national organization for building merchant ships was established and the expenditure of $500,000,000 for this purpose was authorized.

On April 6, 1917, the Declaration of War against the Imperial German Government was signed by President Wilson.

In May, 1917, General Goethals, who was then general manager of the Emergency Fleet Corporation, discussed with the officers of the American International Corporation of New York the program then laid down by him of utilizing to their maximum all of the existing shipbuilding yards and, in addition to this, the construction of new shipyards in which several million tons of ships could be manufactured faster than they had ever been produced.

For several years prior to the war, the total output of all the yards of the United States only once exceeded 500,000 deadweight tons per annum, but it was believed that these yards could be crowded up to produce 2,000,000 tons. Still, this was not nearly enough, as it was figured that we needed at least 5,000,000 tons simply to maintain an army of 1,000,000 men in France, to say nothing of getting them over or of increasing the size of this expeditionary force. In other words, it seemed that we must have, simply to supply our own immediate needs, some 3,000,000 tons at the very least, over and above the amount which the established shipyards could produce in a year, and the question was how this tonnage should be secured.

It was admitted that the old methods of construction were inadequate to supply the unprecedented demand, and it seemed that the only way to make good the deficiency was to build a standardized fabricated ship which could be made in quantity. This method of construction contemplated the utilization of going shops all over the country, in which the various parts and pieces of apparatus could be made and the shipyard itself could give its entire attention to the assembling of these parts or units.

It was not until June 30, 1917, on which date the Urgent Deficiencies Act was approved, that the Emergency Fleet Corporation was in a position to act upon the tentative plan submitted by the American International Corporation, and, due to changes in the personnel of the Emergency Fleet Corporation and for various other reasons, the execution of this contract was deferred until September 13, 1917.

The plan, as it had been outlined by the officials of the American International Corporation, was the construction of a mammoth ship assembling yard and the building of numerous ships, all of the same design. In other words, the scheme was to build a very large manufacturing plant and then to undertake the quantity or "mass production," as our English friends call it, of one type of standardized, fabricated ships.

This meant the design of a simple ship, one in which the plates, sections, angles, etc., could be punched and fashioned in the structural steel and bridge shops, for these were the only steel working plants available. The "fabricated ship" was not a new idea, nor was it developed over night, but, as a matter of fact, the germ lay in embryo form for years and only the national crisis caused it to be hatched full fledged to meet the sudden exigency.

Many of the old shipbuilders ridiculed the plan of the American International Corporation, saying that the scheme was impracticable, that the shipyard was too large and that the plates punched and bent in so many different shops would not fit.

None of those "old-timers" had ever been able to get an order to build a large number of ships all of one design, and the scheme had never been fully tried out and was therefore something of an experiment.

The officers of the American International Corporation, however, due to their experience in the operation of the New York Shipbuilding Corporation at Camden, N. J., where the parts of the ships were "fabricated" in their own yard, believed that it could be done and offered to construct a new shipyard in which 50 ships could be built at one time and where a proportionate number could be outfitted at the same time. To build a shipyard with 50 ways was an audacious undertaking, for it was nearly ten times as big as the ordinary shipyard in this country and nearly one-quarter as large as all of the shipyards in Great Britain combined, the reputed capacity of that historic shipbuilding country being only 209 ways.

It was believed that the American International Corporation was better able to undertake this colossal job than any other organization in the country, for the men at the head of it were courageous, were familiar with big affairs, and were willing to stake their established reputations that it could be done. In the first place, the American International Corporation could of itself control sufficient capital to put through almost any enterprise, regardless of its size. It had a capitalization of $50,000,000 and, besides this, a strong financial backing. Secondly, it could secure the services of the engineering and construction organization of Stone & Webster, inasmuch as Mr. Charles A. Stone, president of the American International Corporation, was the senior partner of the firm of Stone & Webster. This organization had been for many years a leader in executing large engineering and construction undertakings. Thirdly, it could also supply the shipbuilding talent of the New York Shipbuilding Corporation, for the controlling interest in this company had been bought by the American International Corporation, and it was well recognized that it had one of the best developed shipbuilding plants in the country.

The American International Corporation offered to build the shipyard at cost. Its offer was accepted, and it has done better than this: it has not only built a plant costing over $50,000,000 for which it has received no fee whatsoever, but it has put up $1,700,000 of its own money to purchase the land and has paid out of its own pocket all of its overhead expenses.

The scheme to build a shipyard five or six times as large as the largest in the country and to assemble or manufacture ships as automobiles are manufactured was a bold one. There were no precedents to follow, much pioneering work had to be done, and many engineering guesses had to be made. There was no time to make complete plans in advance, but the work had to be started at once, and the development of the plans had to be made as the construction proceeded. "Speed" was the essence of the contract and has been the guiding motive from start to finish. The importance of getting the yard finished at the earliest possible moment is perhaps best realized when one considers that the commercial rental value of the 180 ships under contract, at rates fixed by the Chartering Committee of the United States

Shipping Board, is $460,000 per day, or nearly $14,000,000 per month, to say nothing of their value as a factor in determining the duration of the war.

By a fortunate coincidence, a company affiliated with the American International Corporation had for months been considering the development of a large port terminal, and in their investigations they had studied every available water front property of any considerable size between Boston, Mass., and Baltimore, Md.; knew the location of each of these, the prices for which they could be bought and many of the physical facts surrounding them. All of this valuable data was immediately available when the contract was signed. The locations between Boston and New York were promptly eliminated because it was obvious that any yard built in that territory would be dependent on one single railroad, which was then already overburdened. Locations directly around New York could not well be considered because other shipyards already established in that neighborhood needed all the men they could get. The most desirable location which presented itself, after eliminating the others one by one, was the tract of land near Philadelphia, on the Delaware River, called Hog Island. The arguments in favor of accepting this location were as follows:—

First, the tract of land contained 846 acres, nearly level, entirely vacant, and could be acquired by purchase from one individual and at a reasonable price.

Second, it was on deep water, for the Delaware River has a 35-foot channel directly in front of Hog Island, which runs to the sea.

Third, it was inland, away from enemy attack, being practically 100 miles up the river from the Delaware breakwater.

Fourth, it was on fresh water, for, while there is a tide of some 5 or 6 feet, the water is not even brackish.

Fifth, it was near a large industrial city, from which labor could be drawn and in which some housing facilities could be obtained.

Sixth, it was so located that direct connections could be made with three of the large railroad systems—the Pennsylvania Railroad, the Philadelphia and Reading Railroad, and the Baltimore & Ohio Railroad.

Seventh, it was the nearest available point on tidewater to the steel mills and fabricating shops of Pennsylvania and of the Middle West.

Eighth, it was possible to secure from an already established power plant the electric energy needed to run the shipyard.

In attempting to write a history of the development of Hog Island, it is an almost impossible task to describe chronologically the steps which took place, especially as conditions changed almost daily and as engineering and construction proceeded hand in hand.

The first sketch of the yard is like the ultimate development in only one particular—they both contemplated building fifty shipways. A good sized shipyard in pre-war days contained five or six ways, and this seemed to be a workable unit. It was desired to turn out in this new yard a million and a half deadweight tons per year, and it was thought that, when the yard was under full swing, four ships

per way could be built each year. The conclusion, therefore, was reached that fifty ways, operated in ten groups of five ways each, would be adequate and workable.

The experience of the New York Shipbuilding Corporation indicated that it required only about half as long to outfit a boat as to get it ready for launching—this ratio of course being more or less flexible—so that to have ample room for outfitting, a wet basin with seven piers, each 1,000 feet long and accommodating four ships, or a total of twenty-eight, was planned and a general utility pier between the ways and the outfitting piers was decided to be advisable.

It was expected at the outset that Hog Island would build a vessel of only one type, this being the 7,500-ton, 11½-knot cargo ship, 400 feet long and 54 feet wide, and the original plans and estimates were made on this basis, but the second order for ships given the corporation was for an 8,000-ton, 15-knot combined troop and cargo ship, 450 feet long, 58 feet wide. This change made many alterations in plans necessary, added much to the cost, and prolonged the time of completion of the yard.

Looking at the plan of the yard as it is now being constructed, the track layout excites interest, and a study of it shows its simplicity. As ships were to be manufactured in quantity rather than built singly, it was evident that adequate storage space must be provided for piling up plates, sections and other parts so that they would be ready for immediate use. The plan of storage adopted was that of piling together all plates of the same kind or number, and it was hoped that material for twenty-five boats might always be "in stock" so that the manufacture of ships might go on uninterruptedly, and the storage space was laid out on this basis. Unfortunately, however, this ideal has never been reached, for while there are sizeable piles of some material, the stock of other shapes is still small.

The loaded freight cars come in on a branch of the Pennsylvania Railroad at the northwestern end of the yard from one of the three trunk lines, and enter the main classification yard, where they are sorted out. These cars then discharge the steel in one of the two main storage yards, that for the "A" or 7,500-ton boats goes to the "A" yard and that for the "B" or 8,000-ton boats goes to the "B" yard. Each shipway, it will be noticed, has a track running down its full length, and each outfitting pier has two tracks on it. Tracks are also carried to each of the warehouses and to all the shops. Then there are also two smaller yards, called the "C" and "D" yards, which are primarily for the storage of material other than steel. The total standard gauge track within the shipyard aggregates 80 miles, and the company operates 450 of its own cars, as well as 20 locomotives and 70 locomotive cranes.

A casual observer of the plan of the track layout might criticise the "neck of the bottle" which appears between the "A" and "B" yards. The answer to this criticism is that, while provision has been made for additional tracks at this point, the actual operation thus far shows that they are not needed. It will also be noted that each warehouse and each outfitting pier has a roadway on which materials

can be handled by truck. The total roadways within the plant aggregate 18 miles and motor-driven vehicles are used exclusively.

It was stated earlier in this paper that the fifty shipways are divided into ten groups of five each. As a matter of fact, each five ways are operated as independent shipyards, and each yard has its own administration building, service building and tool building. Each way is provided with four steel towers or derricks, and each derrick has two wooden booms, so that there are eight "hooks" per ship, a total of 440. This system of handling material was decided upon because of the difficulties of obtaining an adequate number of traveling cranes with the necessary steel for supporting them. The towers took much less steel, and wooden booms were easily and quickly constructed.

Forty of the shipways are on wooden pile foundations, while ten are concrete ways, erected on concrete piles. The use of concrete gave a diversity factor in construction material and made an admirable fire break in the mile and a quarter of ways.

Between each of the yards there is an air compressor plant, serving two yards, but the supply piping is so connected through the entire shipyard that any individual compressor plant may be by-passed in case of accident. The outfitting piers also have two compressor plants. The total capacity of these plants together is 75,000 cubic feet of air per minute, which makes it the second largest compressor installation in the world, the one at the Rand Mines in South Africa alone surpassing it.

Directly back of the ways buildings and also at the head of the outfitting piers are numerous warehouses in which the lighter, fragile and perishable material is stored. These are one-story buildings and they are each divided into four sections by fire-walls, thus minimizing the conflagration hazard. In addition to this, there is nearing completion a large, four-story concrete warehouse, the floor area of which is 400 feet by 172 feet.

Directly in the center of the plant is the group of executive buildings, the principal one of these being the administration building, which houses the president and several vice-presidents and their assistants, the accounting organization, purchasing department and, besides this, the local representatives of the Emergency Fleet Corporation, who are in direct supervision of the Hog Island plant for the Government.

The adjoining building, originally designated as the engineers' building, is now called the ship administration building. This contains the engineers and the large draughting force. Next in order comes a central garage and then the employment building. The employment department at Hog Island is called the Industrial Relations Department, as the organization has to do not only with the employment of the men but also their welfare and housing. Admission to the employment department is made possible through a special gate, where no passes are required. All other gates at the yard require a special pass or identification tag before anyone can enter.

Directly opposite the administration building is a cafeteria, in which light luncheons are served to the clerks, foremen and any others who may wish to eat there. Across the street from the ship administration building is located one of the best first-aid hospitals in the country. It is manned by an efficient staff of doctors and nurses. It has an operating room, a first-aid room, a modern X-ray outfit, a ward with twenty beds, a dentist's chair, which is in operation 24 hours a day, and four motor-driven ambulances. There is also in this same group of buildings a fireproof telephone plant, which contains a 22-position switchboard and maintains connections with 2,000 stations scattered throughout the island, this plant being equivalent to that used in an ordinary city of 50,000 population. Adjoining the telephone building is the fireproof reenforced concrete records building. In it all the operating records are kept and the Powers card record system of following all shipments from the time they leave the factory to the time they are placed in position on the ship. Besides the above, there is a guards' barracks, which houses 200 of the guards and also contains a room in which a district magistrate holds court each day. Adjoining this is a small jail. A fireproof brick "bank" building, so called, is also found in this group. It is primarily a depository for the pay-roll funds and was found necessary as all employees are paid off in cash each week. In this group, as in all of the other groups of buildings, there is a local central heating plant, which furnishes steam to all the buildings by means of insulated overhead pipes.

Perhaps next of importance are the shop buildings. They are located toward the eastern end of the yard, near the "A" storage yard and back of the shipways. As we approach the shops from the west, we first reach the air tool shop, which is devoted entirely to keeping in repair the 6,500 air tools—riveters, reamers, drills, grinders, etc.—which are used on the job. Next come the galvanizing and pipe shops and then two machine shops. The largest building in the plant is the plate and angle shop, which is 638 feet by 223 feet. This is arranged with three bays, each bay having two traveling cranes. It is equipped with furnaces and bending tables, rolls, punches, shears, etc. Next is the template shop, which needs no particular explanation except the statement that, when building fabricated ships, templates have to be made for every piece of steel entering the ship. The plate and angle correction shop, as its name would imply, was erected more or less as an emergency shop to take care of errors and omissions in fabricating and to act as an insurance against fires, strikes or losses in shipment, which might delay deliveries from outside shops.

The shop plant at Hog Island is comparatively small, as more than 95 per cent of all the material entering the ships is being fabricated in outside shops. There are a few plates which are being taken care of in the plate and angle shop. There are smith shops in the group, one for solid work and another for miscellaneous smith work.

Besides the buildings already mentioned are two structures called the ship foundation template buildings. In one of these the complete power plant for the

"A" boat has been erected, consisting of three Babcock & Willcox boilers, a 2,500 horse-power General Electric (Curtis) geared turbine, with its heater, pumps, condensers and other auxiliaries. This installation was made for the purpose of instructing the installation crews, students and others, and to make sure that all the calculations and measurements of the engineers and draughtsmen had been properly made. In like manner the other ship foundation template building contains a "B" installation, consisting of six Babcock & Willcox boilers, a 6,000 horse-power General Electric (Curtis) turbine, and the auxiliaries. This entire group of buildings is also heated from a local, central heating plant.

Outside the yard are the living quarters. Here there are barracks for 6,000 men. Each building is a two-story structure and houses 100 men in eight separate wards. These compare most favorably with the army barracks. There is a second guard barracks here which accommodates 200 guards. (A third one is located in the extreme eastern end of the yard.)

The hotel, used principally by the officials, heads of departments, chief assistants and guests, is modern in every respect, and good meals are served here at cost. One of the four fire stations is located here. The department contains 100 men and 16 motor-driven pieces of apparatus. The other three fire stations are located at strategic points within the yard.

There are two large temporary mess halls near the barracks, but these have been practically discontinued as now the workmen are fed in the service buildings near the ways. During the construction period some 13,000 meals were served daily in these mess halls at 30 cents each. In all, there are at present fourteen eating places on the island, beside the large cafeteria and hotel.

A Young Men's Christian Association building completes the living section of the plant. Its auditorium seats 2,000. It also contains a large gymnasium, twelve billiard tables, locker rooms, shower baths, besides numerous class-rooms on the second floor. These buildings are all heated from a local central plant.

As Hog Island is outside of the limits of the city of Philadelphia, it was necessary to establish its own local utilities. A domestic water plant, taking water from the Delaware River, together with a filtration and treatment plant, was installed. To distribute this drinking water through the island requires 120,000 feet of piping. A high-pressure piping system for sanitary and fire purposes also covers the island. This requires 90,000 feet of pipe, and raw water is furnished from three motor-driven pumping plants. The ordinary operating pressure is 80 pounds, but on the outbreak of a fire it is run up to 200 pounds. There are 260 fire hydrants systematically located. A complete sewerage system has been put in with two Imhoff tanks and necessary sludge beds. Sewer lines are 73,000 feet in length, and the capacity of the system is ample for a population of 35,000. Electric power is used throughout the yard. The current, purchased from the local company, comes in over a steel tower transmission line at 66,000 volts and goes to a sub-station near the center of the yard. The capacity of this sub-station is 30,000 KVA of which 6,000 is reserve, and the connected load is something over 40,000 horse-power.

The various electric systems require about 3,000,000 feet of cable, all of which has been placed underground. There are 900 motors in the yard, ranging from 1/30 horse-power to 1,000 horse-power in size. The yard, especially around the ships, is well lighted with flood lights and otherwise. Eighty thousand lamps of all kinds are in use here.

There are two fuel oil tanks, each holding 100,000 gallons, from which pipes are run to the principal shops where the fuel is used in the furnaces. The present consumption is about 1,200 gallons per day.

To get to Hog Island during the construction period was difficult, as there was no regular transportation to the yard. The nearest lines were a mile away, while others were a mile and a half off. At the present time these difficulties have been removed, as a physical connection has been made with the steam lines and a large loop established within the yard, having three stations, each about half a mile apart. Service is furnished by ten trains, carrying from ten to fourteen cars each. An extension of the Philadelphia Rapid Transit Company now furnishes excellent trolley service direct to the island, and connection is thus furnished with all the lines of this company throughout Philadelphia. The Philadelphia and Southwestern Company, an independent line, also cares for a few thousand men who live in the southern section of Philadelphia. Two large steamboats also run from the wharf at way No. 10 direct to the foot of Chestnut Street, Philadelphia, and one runs across the river to Billingsport, New Jersey.

The force at the island at the present time is about 30,000, one-half of whom are at work on the ships, some 9,000 are on operation or maintenance of the plant, and 6,000 are still on yard construction. The yard, however, is practically finished, and when the manufacturing of ships is at its height the total force will run between 30,000 and 35,000. The weekly pay-roll is now about $1,000,000. Standard union wages are paid on construction work, and the ship workers are paid on the basis established by the so-called "Macy Wage Adjustment Board." There is some piece work and this will be extended as the work progresses.

On September 13, 1917, the date on which the contract was signed, Hog Island was a desolate waste. One week later construction began and went on continuously throughout the winter, so that on February 12, 1918, the first keel was laid and on August 5th the first ship was launched and at this date, October 5th, there are 40 other ships under construction and three at the outfitting piers.

As one looks at the shipyard, practically completed in eleven months, it is hard to realize the difficulties encountered in making it a possibility. Last winter was the coldest on record in Philadelphia, and the frost got into the ground to a depth of 42 inches as compared with 24 inches in an ordinary winter, so that it had to be blasted out with dynamite or thawed out with live steam before the piles could be driven. The thermometer for two months was below freezing point most of the time, and on several nights it went below zero and there was no shelter from the wind which swept across the island. The trenches were continually full of water and ice and, as a matter of fact, hundreds of men had their feet, hands and

ears frozen. It took on an average an hour and a half to get to Hog Island, or three hours each day was spent by most of the men on the cars during the short winter days. The wonder is that during this cold weather any work was accomplished.

The labor turn-over during these trying months was of course high, but, as winter moderated and transportation improved, it decreased, so that at the present time the turn-over is only about 35 per cent per month. This is of course decidedly higher than it should be, but it is simply typical of what is going on all over the country. Even the best of conditions do not prevent the laborers from migrating. The executives, and in fact the entire office staff, worked with the greatest enthusiasm for uncounted hours during the early days and until they were branded as "thieves, profiteers and grafters," when the spirit broke down and the morale of the organization came near going to pieces.

Little by little, however, as the work progressed, as the yard neared completion and as ships began to take shape and finally the launchings began, criticism has died away and now unbounded praise has taken its place. The *esprit de corps* has come back and everyone is now doing his best. The organization is complete, the entire enterprise is functioning properly and ships will be manufactured at an unheard of rate—from two to three each week. This is the program which was outlined at the start and it will be lived up to. Already three have been launched and are lying at the outfitting piers, where they are fast nearing completion. There are four 35-ton gantry cranes installed on each outfitting pier and a 100-ton bridge crane has been installed, under which any of the ships can ride with masts in place. The outfitting piers are 1,000 feet long and 100 feet wide and, by dredging out some 6,000,000 cubic yards, a 23-foot depth of water is being secured.

The plant is now in condition to turn out a million and a half deadweight tons of ships per year and, as one of the engineers on the job has said, "It would be no trick at all to get out two million deadweight tons if we could be assured of the steel and the other supplies necessary."

This million and a half tons of ships calls for half a million tons of steel, for 90,000,000 rivets, for 570 boilers, for 700,000 horse-power of steam turbines, and this material must all come in regular order and in an established sequence. It can't be done, our critics still say, but it is being done. The capacity of the yard at the present time does not depend on the yard itself, but on the shops elsewhere from which it draws its supplies. All the steel plants in the country are being taxed to their utmost, but it is believed that American ingenuity, American enterprise and American push, together with American loyalty, will solve all these difficulties, and that this fleet of 180 ships will be completed and turned over to the Government faster than a like number of ships has been built in the history of the world.

DISCUSSION.

THE PRESIDENT:—I am sure we are indebted to Mr. Blood for this paper. If there is no discussion, I will extend to Mr. Blood, on your behalf, the thanks of the Society.

Gentlemen, my term of office is nearly over, but before leaving this part of my closing work I wish to present to you the President-elect, Admiral Washington Lee Caps. (Loud applause.)

PRESIDENT-ELECT CAPPS:—Gentlemen, the purpose for which I came to the platform was not to receive your acclaim, grateful though it may be. It is a far more important purpose, but, before proceeding, will you please permit me to express my very great appreciation of the honor which you conferred upon me yesterday? Having, with Commander Taylor, been associated with the Society from its infancy, you can easily imagine what a very great and profound satisfaction it is to me to be honored with the highest office in your gift on the twenty-fifth anniversary of the creation of the Society. All I need or can say further in that respect is that I shall do my utmost, with your hearty cooperation, to give to the Society as nearly as possible a continuance of that fine direction which has been given by my predecessors. We have been twenty-five years in existence and have had only four presidents, and I think a great part of our success is unquestionably due to the comparatively long period that our principal executives have remained in office.

The particular purpose for which I have relieved the chairman temporarily is to make a motion which he cannot appropriately put while chairman. He is now about to complete a second period of service of three years as your president. During an intervening period he also bore a large part of the burden of the direction of the affairs of the Society, due to the illness of the incumbent, Colonel Thompson. From the very inception of the Society he has shown an interest and a fine direction which has, in large part, made possible the success which has attended our efforts.

The hour is late, and I should undoubtedly be doing the correct thing if I followed distinguished legislative precedent and asked "leave to print." But it is not necessary to indulge in any extended eulogium of President Taylor by reciting his services. You know about them almost as well as I do, and it is one of the greatest privileges that I have, in offering you an opportunity to make fitting avowal of the esteem in which you regard him. But before doing that formally, I will return to parliamentary procedure, and give to my colleague, Vice-President H. D. Goulder, the opportunity of seconding such a motion.

MR. H. D. GOULDER, *Vice-President*:—Mr. President and gentlemen, I am very happy to second a vote of thanks to our retiring president. I do not know that you technical gentlemen consider how much you are being appreciated for the wonderful work that you are doing. And now, when somebody tried to stop the clock of history and we have got to start over and regulate it, does anyone connected with the Society fully realize the value to this country of the work done by Clement A. Griscom and by Stevenson Taylor, and the work to be done now, because this Society of Naval Architects and Marine Engineers is going to be, and is—but is going to be more so—a tremendous factor, and it is going to be

more respected and more influential because of the work which Mr. Stevenson Taylor has done. I now second the motion for a very hearty expression of esteem to Mr. Stevenson Taylor, on behalf of the Society, and I think I can go further and say that many people will appreciate that the Society, in giving that expression, honors itself.

President-Elect Capps:—Gentlemen, you have heard the motion. I ask you to rise and give expression to your feelings just as strongly as you see fit.

The entire assemblage rose and gave three rousing cheers to Mr. Stevenson Taylor.

President Taylor:—Gentlemen, I thought I had made a real farewell speech six years ago, but the members of the Society seemed to demand that I should take the second term now drawing to its close.

I do not know how it is possible for me to express to you my appreciation of the many honors that you have conferred upon me. I now surrender this office with some sense of relief, but I would be unjust to myself did I not endeavor to say to you what a great pleasure I have had in serving as your president. This pleasure has been brought about in a very great measure by the hearty cooperation of every member of the Council, the past presidents, the vice-presidents, the honorary vice-presidents, the secretaries and treasurers, as well as the members-at-large.

In looking back on the last ten years, during which I have been honored by your confidence and support, I recall that I have served you for two terms of three years each, and, as Admiral Capps said, most of the term during the interim when Colonel Thompson was president; and also during the last year of the term of Admiral Bowles, while he was absent in Europe and South America. It is an experience of great satisfaction to me to know how well you have all seconded my efforts for the advancement of the Society.

I sincerely thank you, gentlemen. That phrase of Hamlet comes to my mind—"Beggar that I am, I am even poor in thanks, but I thank you." (Applause.)

I wish to call attention to the fact that you should register at the Gold Room Headquarters in the Bellevue-Stratford, so that you may take such excursions as you choose.

In relation to the banquet, to which we are refusing any further subscriptions on account of having sufficient to entirely fill the hall, I promise you a very interesting evening. The local committee has been especially active, and has done its work exceedingly well. I am sure that every one who attends the banquet will be pleased.

The Secretary advises me to call the members of the Council to the front at the close of this meeting, just for a short session.

The meeting is now closed.

APPENDIX

GREETINGS AND RESPONSES TO AND FROM SISTER SOCIETIES IN GREAT BRITAIN, FRANCE AND ITALY

CABLEGRAM

PHILADELPHIA, PA., U. S. A.,
November 13, 1918.

INSTITUTE OF NAVAL ARCHITECTS,
Adelphi Place, London, England.

American Society of Naval Architects and Marine Engineers now celebrating in Philadelphia its twenty-fifth Anniversary congratulates the members of its sister society in Great Britain upon their brilliant achievements during the war now so gloriously ended.

TAYLOR,
President.

Secretary, R. W. DANA. FOUNDED 1860.

INSTITUTION OF NAVAL ARCHITECTS
Incorporated by Royal Charter, 1910.

5 ADELPHI TERRACE, LONDON, W. C. 2,
21st November, 1918.

DEAR MR. STEVENSON TAYLOR:—

I am desired by the president to acknowledge the receipt of your very kind telegram of the 17th inst., conveying the good wishes of our American friends to the Institution of Naval Architects, in reply to the president's telegram of congratulation on the conclusion of hostilities.

I feel sure that the Council will be very gratified to receive this expression of the good-will and kind feelings of the Society of Naval Architects and Marine Engineers in America towards their colleagues in this Institution.

With kindest regards,

I remain,
Very sincerely yours,
R. W. DANA,
Secretary.

STEVENSON TAYLOR, ESQ.

CABLEGRAM

November 13, 1918.

STEVENSON TAYLOR, c/o Socarcheng, New York:—

Council Institution of Naval Architects send hearty congratulations to their American colleagues and Allies on victorious termination of war. The links that unite our peoples have been firmly welded in this great struggle for liberty.

EARL OF DURHAM,
President.

Secretary, R. W. DANA. FOUNDED 1860.

INSTITUTION OF NAVAL ARCHITECTS

Incorporated by Royal Charter, 1910.

5, ADELPHIA TERRACE, LONDON, W. C. 2,
14th November, 1918.

DEAR MR. TAYLOR:—

I have much pleasure in informing you that at our last meeting of the Council it was unanimously resolved to send the following message of congratulation to you as president of the Society of Naval Architects and Marine Engineers:—

> "Council Institution of Naval Architects send hearty congratulations to their American Colleagues and Allies on victorious termination of war. The links that unite our peoples have been firmly welded in this great struggle for liberty.
>
> "EARL OF DURHAM, *President.*"

The above message was telegraphed to you yesterday and, I hope, reached you safely.

I need not tell you how deeply we feel that the great results achieved by this war have been due in large measure to the complete harmony and accord that have subsisted between the Allies throughout the war, and to the singleness of purpose that has characterised the objects for which we have fought and which have now been gloriously achieved.

I remain,
Very cordially yours,
R. W. DANA,
Secretary.

STEVENSON TAYLOR, ESQ.

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
ENGINEERING SOCIETIES BUILDING
29 WEST 39TH STREET.

NEW YORK, N. Y., *December 11, 1918.*

MR. R. W. DANA, *Secretary,*
Institution of Naval Architects,
5 Adelphia Terrace, London, England.

DEAR MR. DANA:—

Your letter of November 14 has just reached me and your cable of congratulations to The Society of Naval Architects and Marine Engineers was received on the 16th of No-

vember, too late, I am sorry to say, to be read at the close of our meeting on November 15 at the banquet in Philadelphia, Pa.

We reciprocate heartily the expressions of your cable and letter and sincerely hope that all questions relating to the settlement of the great war will be determined with the same singleness of purpose that has characterized the actions of the Allies throughout the war.

I am happy to say to you that my term as president expires on December 31 and that to succeed me Rear Admiral Washington L. Capps, U. S. N., has been elected.

We had a very successful meeting on the 14th and 15th of November and have added the names of about 500 new members to our list.

Assuring you of the great pleasure I had of hearing again from you personally, I am, with sincere regards,

Yours truly,
STEVENSON TAYLOR,
President.

CABLEGRAM

PHILADELPHIA, PA., *November 13, 1918.*

ASSOCIATED TECHNIQUE MARITIME,
Paris, France.

American Society of Naval Architects and Marine Engineers now celebrating in Philadelphia its twenty-fifth Anniversary congratulates the members of its sister society in France upon their brilliant achievements during the war now so gloriously ended.

TAYLOR,
President.

PARIS, *23 March, 1919.*

MR. PRESIDENT AND DEAR COLLEAGUE:

I received yesterday, March 22, from Mr. Hart, member of the council of L'Association Technique Maritime, a letter from Mr. Daniel Cox enclosing a copy of a message that you were kind enough to cable me on November 13, 1918, the twenty-fifth anniversary of the foundation of the Society of Naval Architects and Marine Engineers.

This message contains felicitations for which we are deeply grateful concerning the part taken by the French Army in our common victory.

During November, 1918, I was in the country a short distance from the American camp in front of Cherbourg. I have a great admiration for your superb soldiers and I consider that you have returned a hundred-fold the aid extended to the United States of America in its infancy by Lafayette and Rochambeau. Your appreciation of our aid has been shown after an interval of one hundred and thirty years—the appreciation of France in the same manner should extend over a period of thirteen hundred years. We will not be found wanting.

I am not unmindful of the date on which you sent to us your cordial message—the anniversary of the Society of Naval Architects and Marine Engineers—and I wish to thank you in the name of our Society and to extend our felicitations for the happy development of your Society and my best wishes for the continuance of its prosperity.

Believe me, Mr. President and dear colleague,

Your sincere friend,

L. BERTIN.

Congratulations also for the magnificent development of vessel construction in the United States.

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
ENGINEERING SOCIETIES BUILDING
29 WEST 39TH STREET.

NEW YORK, N. Y., *November 27, 1918.*

MR. N. SOLIANI,
Gio Ausaldo & Co.,
Sestre Ponente, Italy.

DEAR SIR:—At the recent meeting of the Society, instructions were given me to send the following cablegram to the Italian Society of Naval Architects:

> "American Society of Naval Architects and Marine Engineers now celebrating in Philadelphia its twenty-fifth Anniversary congratulates the members of its sister society in Italy upon their brilliant achievements during the war now so gloriously ended.
>
> "TAYLOR,
> *President.*"

Owing to the fact that I could not ascertain the name of the Society, I endeavored to send the cablegram to you with the idea that you would convey the sentiments expressed therein to the Society in Italy. As the telegraph cables abroad were overburdened with messages we could not send the cablegram so that it would be delivered within a reasonable time. I am therefore communicating its contents by letter and trust that you will place it before the Italian Society.

Yours truly,

DANIEL H. COX,
Secretary-Treasurer.

Collegio degli Ingegneri Navali e Meccanici in Italia
Via Carlo Alberto, N. 18

Genova, *li 15th January, 1919.*

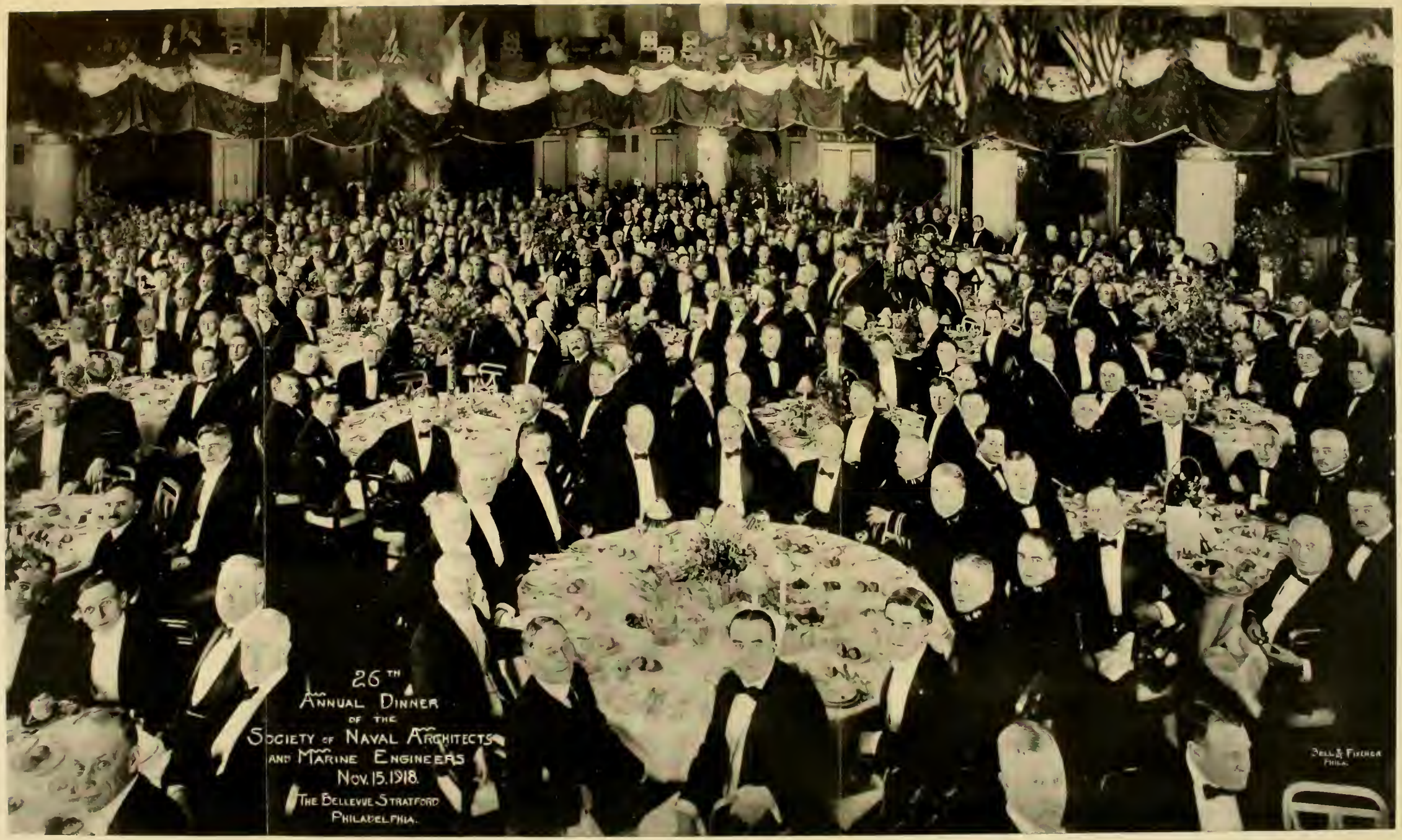
To the President of the
American Society of Naval Architects and Marine Engineers,
29 West 39th Street, New York.

Dear Sir:—

On the twelfth instant, at the general meeting of this Society, your noble message, received through Colonel Soliani, was duly communicated and was warmly welcomed and enthusiastically cheered. It is now my pleasant task to convey to your Society the warm thanks of our own for their kind and gentle greetings, and tell them how greatly appreciated they have been, and how reciprocated they are, as an expression of the friendly sentiments linking our two countries, and which the gallant sons of your great nation have brilliantly cemented on the Italian battlefields with the sons of Italy.

Yours truly,

A. SIVIBANTI,
Propresident.


26TH
ANNUAL DINNER
OF THE
SOCIETY OF NAVAL ARCHITECTS
AND MARINE ENGINEERS
NOV. 15. 1918.
THE BELLEVUE-STRATFORD
PHILADELPHIA.
BELL & FIELDER
PHILA.

TWENTY-SIXTH ANNUAL BANQUET

OF

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

HELD AT THE

BELLEVUE-STRATFORD HOTEL, PHILADELPHIA, PA.

FRIDAY EVENING, NOVEMBER 15, 1918

REPORT OF SPEECHES AT THE TWENTY-SIXTH ANNUAL DINNER OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS HELD AT THE BELLEVUE-STRATFORD, PHILADELPHIA, NOVEMBER 15, 1918.

Before the service of the dinner, the divine blessing was asked by the Rev. Floyd Tompkins, D.D., and this was followed by the company singing "Praise God From Whom All Blessings Flow."

After the service of the coffee and cigars, Lieutenant Commander Stevenson Taylor, president of the Society, acting as toastmaster, called the company to order and said:

Ladies and gentlemen, on this beautiful menu, the handsomest we have ever had—and we have had some good ones—the first in order is the president's address. I have no intention of making an address, because we have secured men to be present at this banquet who are much better speakers.

There are many themes that one could speak about to-night, but I dare not venture on more than one. Four and one-quarter years ago a great empire,—an empire so great and one that had progressed so much in the previous twenty-five years that I feel warranted in saying that had they been allowed to continue along the lines of science, trade, commerce, and maritime development, they could have had the world by the throat; but this same empire, populated by the greatest egotists of the world and led by the greatest military egotistical government of the world, were not satisfied. They took advantage of a quarrel between one of their own vassals and a minor kingdom, tore into pieces treaties as scraps of paper, and started a debauching march through the innocent kingdom of Belgium and down into the innocent republic of France, showing their contempt of the Christian world as they went along, by taking Gott in partnership with them, not our God, but their own tribal god.

They showed contempt, also, for the great republic of the United States of America. They had debauched Belgium, they had debauched France, they sank ships with our people on board, they did everything that was frightful—violating every law of humanity—until finally they drove the United States of America into the war just a year and a half ago, and now the great empire has fallen. Their leaders, like yellow dogs, have fled from their fate, and their people are now begging for bread.

"How have the mighty fallen"—a greater fall was never known in history, and, praise God, I do not believe there will ever another one be known of the same kind. (Applause.) The people of Germany are asking for bread, and when we think of what the people and the government of Germany have done we are tempted to say:—"You shall have no bread."

But there is not a man in this audience who would see a person starve, even if he were the greatest criminal. We must be merciful, but we must reverse the usual order of things; we must temper our mercy with justice (applause), a justice so complete that never again so long as this old world lasts shall there be a repetition of the horrors of the last four years. That is the only theme on which I dare venture to speak, because I must not interfere with the subjects of those who will follow me. In connection with this matter of justice I wish to say that I did my best, aided by our good friend on my right (Secretary Daniels), to have with us to-night a guest to address you who would have cheered your hearts, but in reply to my invitation for him to be present, I have received this letter:—

THE WHITE HOUSE
WASHINGTON

22 October, 1918

My dear Mr. Taylor:

Knowing, as I do, the very valuable services which the Society of Naval Architects and Marine Engineers have rendered the country in these days of stress, it is a peculiar disappointment to me that I cannot join the Society at its annual banquet on November 15th. I am sure that the members of the Society will know that I am kept away only by a pressure of public duties which clearly deprives me of the right to seek my own pleasure.

Cordially and sincerely yours,

Woodrow Wilson

Mr. Stevenson Taylor, President,
Society of Naval Architects and Marine Engineers,
66 Beaver Street, New York.

THE TOASTMASTER:—The first toast always at our banquet is—"The President of the United States."

The entire company drank the toast "To the President of the United States" and joined in singing "The Star Spangled Banner."

THE TOASTMASTER:—The next toast on our program is "Our Army." Col. Samuel Huff, of the U. S. Army, was to have responded to this toast, but he was called to Washington last night, word of which I received this morning, and one of the impertinent things I have done is to solicit a man, unprepared, without notice, to respond to this toast. When I introduce to you the speaker, you will realize that I was justified. It gives me great pleasure to present to you Judge Joseph Buffington, of Pittsburgh.

ADDRESS OF JUDGE BUFFINGTON.

Mr. Toastmaster, Mr. Secretary of the Navy, ladies and gentlemen, guests and members of this Society, my little Scotch-Irish wife out in Pittsburgh sometimes says to me when I am unexpectedly called on to make an unlooked-for address: "Well, whatever else you do, don't begin by apologizing." It is a little tough, however, to be commandeered and stood up before this firing line and in this presence to-night. One feels a sense of responsibility in setting the keynote and being the forerunner of that brilliant galaxy of men who will later shoot down the oratorical toboggan and seek to entertain you as they whiz past. For my part, I feel somewhat like the man who had a slight domestic trouble which ended in a minor assault upon that treasured member of his household, his wife's mother, and for which he was hailed into the police court. The wise man who presided in that august tribunal was evidently one who had troubles of his own also, for, after hearing the case and duly considering the provocation, he fined the assaulter $5.25. The defendant, gratified at the justice and moderation of the sentence, said: "Judge, I appreciate the $5 fine, and, between ourselves, I think that is about right and that you understand the situation, but I don't quite grasp the 25 cents that you have added." "Brother," said the judge, "that is the war tax on amusements."

Now, my friends, that volley of rapid-fire applause cheers me immensely. It is a hard thing for a stranger to try out a story on a strange audience and have no one catch on until the second section comes along, but you chaps have caught on to the first section, so I may try another. But, really, you know, without making any apologies, to get a man up and commandeer him here to speak for the Army in the presence of the Navy—why, I feel just about like one of those Scotch-Irish preachers whom I am encouraged to tell you about—and by way of parenthesis I might say just here that you had better prize the religious matter that comes in on the early part of the toboggan program, for as I look down the roster and see that it ends with Schwab, I am satisfied the religious and spiritual part may reach the depths of ebb tide when C. M. wades in.

But to digress from Schwab to the two Scotch preachers. I feel like one of them—I mean one of the preachers, not Mr. Schwab—as I stand here to-night. These clericals got to discussing—Dr. Tompkins, I am glad to see you so deeply interested in this information about the clergy, I beg of you to listen carefully; it may help your flock if you will hear, mark, learn and inwardly digest what I have to say—well, these two Scotch dominies got to discussing how best to prepare sermons, and one said, "Well, now, brither, ye see my way is this: On Monday, of course, it's an off day for the clargy, but Tuesday I start in and I jot down on paper 'Farstly,' and under that I put down a farst part for my dascourse, Wednesday I put down 'Sacondly' and put the sacond part of the dascourse under that cap-

tion. On Thorsday, I put down 'Thordly' and so on until I get to the end of the week, so when the Lord's day comes I rise in my pulpit with a parfectly prepared dascourse." To which orderly layout the other replied: "Aweel, mon, I dinna think much o' yer plan." "Weel," answered the first with some asperity, "and how wad ye do it?" "Weel, brither," he replied, "the trouble wi' yer plan is that as ye jot down the heads o' yer dascourse, the deil is just as busy as the reverend clargy, and I ween he is looking o'er yer shoulder and he sees the whole matter o' yer dascourse, so he gets busy wi' yer congregation instanter, and when the Sabbath morn comes and ye mount yer pulpit the evil one has got abroad among yer people through the week and has discoonted all yer goin' to say." "Well, how do you do it, then," asked the nettled parson. "Why, I use no pad. I commit nothin' to writing and when I get up on the Sabbath morn the deil himsel' don't know what I'm goin' to say." Now, doctor, I commend this practice to you for what it is worth, remarking, of course, that it is only valuable in case his satanic majesty is accustomed to circulate among your parishioners.

But to return to the speech on the Army, which I was commandeered to make and for which you will see I have made no such preparation as the first Scotch preacher, I don't know but that it would be seemly for me to turn from the gospel to the law and follow the example of a lawyer who was at the country bar where I began practice. There was a lot of fun going on there and we had one lawyer at our bar, quite an exception to the general rule, I beg to say, who never would talk much to the point, but the less he had in his case the more he was wont to talk. We called him "old shell the woods," for when he got a case on which he hadn't a leg to stand he would wink to us as he rose to address the jury and say, "Well, I guess there is nothing left for me to do but to 'shell the woods.' "

Now, of course speaking for the Army, they are target hitters, bull's-eye chaps, but if they commandeer a rank and rankless outsider to speak for them the Army can't complain if his projectiles drop in the depths of the forest or if, after the fashion of some other branches of the service, I shoot short or overtop or even sidestep the ship at which I aim. Of course, gentlemen, I recognize that the Army is the Army and the Navy is the Navy, but, after all, they are both built on the substructure of the law. Why, Mr. Secretary Daniels, even you could not build a ship, in fact you could not do anything in the Navy, and the Army, too, could do nothing, and the marines could do nothing, unless some laws were passed first. Really, gentlemen, seriously speaking, the lawyers are at the foundation of everything, and as long as there is no one here to-night to speak for the Army and you force me to speak for it and you compel me to speak first—put me in the shock troops, for which, thanks—because you say that is the proper program for the Navy host toward the Army guest—I recognize that when you had the dominie lead off first with the blessing that next after the gospel marches the law, then the Army swings in and last, but not least, if I am to trust the testimony of that great sailor, the Honorable Secretary of the Navy—last, but not least, trails the Navy.

Now, gentlemen, of course, as I have made no preparation for this occasion I ought to stop pretty soon, but I want to tell you that when I get a chance to make a speech I generally make a pretty long one, and it happens that I have been kept pretty quiet by a couple of law-

yers who talked all day because they were well paid for talking, and to-night I have been sitting here next to the dominie and the admiral who just talked without pay, and alongside me was this fringe of shipbuilders, the whole table length, who also had some conversational powers verging on monopoly, and between the entire bunch there was not much margin left for a modest man for anything but mere absorption of other people's ideas. But now that I am on my feet and have the right of way, I propose to take my own time and I want to tell you by way of encouragement, gentlemen, that I have at times spoken for an entire hour, or even an hour and a half at a time, and with such constraining power that not a single auditor has left even to make a suburban train. That is the truth; but half truths, gentlemen, are very dangerous, sometimes misleading, and if you were to ask Mr. Schwab for the whole of the truth he would tell you that when I made a speech of that character it was at Riverside. And Riverside is the Sing Sing for Western Pennsylvania.

Speaking of going to the penitentiary and making speeches—I will add that I like to mingle with my fellow-men. I like to mingle with you business men, Mr. Secretary. I even like to drop around to conventions of business men. We have a great many conventions in my home town of Pittsburgh, and I might just as well add here, gentlemen, that Pittsburgh is the most convenient place I know of for holding conventions. It is the one and only place in the United States where everybody, from Boston to Richmond, and from St. Paul to St. Louis, can reach in a sleeping car overnight. Providence and geography, gentlemen, made Pittsburgh the convention city of the United States, and while I am glad this convention is here in Philadelphia this year, it can't, of course, be held here next year, so I suggest that you come out to Pittsburgh. We are interested in the Navy out there. We contribute to its armor plate and to the ordinary ship plates that don't want armor, so come out the next time you convene and we will show you where Mr. Schwab learned the shipbuilding business, when he built steel barges of such minimum draught that all the water they needed to run on was mountain dew.

But returning to that "new freedom" that is in the air, and which I feel when I rise from the substratum babel of my seat here at the table and my companions and have the option of uncensored speech, I want to say that during the earlier part of this dinner and while sitting between these companions, in silence, I have stored away some things that were novel—almost startling. For when an admiral of the navy and a dominie of the church get together, there is a mixture of things spiritual and nautical which makes one regret that the stenographer in front of me had not been recording the marine-heavenly converse on this side of the table, that, when reproduced, would have made you feel that you, as well as listening I, had been floating round somewhere between the deep blue sea and its vis-a-vis. But referring to this industrious shorthand gentleman in front of me reminds me that his presence gives great comfort to one with a "made-on-the-spot speech"—and that is the privilege of issuing a revised version. Now the speeches of these other gentlemen who follow on the toboggan are already in print in the newspaper offices of the city. You can read them all in the morning papers and, what is worse, not one of them can deny that he said

what he is reported to have said. But when it comes to my part to correct and issue a revised version which may possibly appear in your minutes, I can put in anything I please, and just here, let me suggest a word of friendly marital advice to you shipbuilders before me. You have to-night the ruddy glow on your cheek and the fire in your eye that evidence the depth of your enjoyment of the spiritual side of this evening. Don't, my friends, when on some later evening at your own fireside you read the proceedings of this convention, and perchance this revised version—don't, I beg of you, be betrayed into saying to your wife, "I never heard him say that"; "I don't remember this." Such a remark may convey an impression to her of the reason why you did not this evening hear and accurately recall all you are now hearing. No, stick by the revised version and vouch for every word of it, and your wife will be satisfied that on this evening you rose to that standard of moderation which the observation of ages has coined into that truism, that you were "as sober as a judge."

I wish, gentlemen, time allowed me to tell you of these theological-nautical dissertations I have listened to here to-night. Of the discussion of my table companions as to whether it was under Secretary Daniel's administration that Schwab built cattleships or Noah built battleships and whether it was Noah or Admiral Bowles who had a launching party 120 years after he laid the keel of his craft, and which great naval architect, Piez or Noah, was associated with Shem and Hurley, Ham and Schwab and Japheth or Bowles, and whether the vessel they launched finally ran aground at Mount Ararat or Hog Island.

But, gentlemen, as I was saying, I like to go to these conventions. I like to mingle with folks. I have a sort of feeling that it don't hurt a judge to get acquainted with business men. I have sometimes thought that fresh air and law and a little knowledge of the common sense of business are not bad things to lodge in the judicial cranium, so I went to this convention last night. I wanted, for example, to learn something of the merchant marine of the United States. I wanted to find out, how, after you built your ships, you were going to run them when you got out into the "freedom of the seas" and came across the Jap and the Norseman and other wage standards than our own. I went to the convention to find out just what you were going to do with our American cargoes when you got them to some point somewhere or anywhere. And about whether you were going to have some American traders, and American banks, and other modern conveniences of home in these foreign ports. I went there to learn about these things and I am still ready to learn, if anybody has got any information to give me.

Then there were other momentous questions. I listened to learned and very spirited conversations on the momentous subject of the "load line." I never knew before what a "load line" was. Until I went to the convention I was never conscious that there was such things as "load lines." I listened to the discussion of that subject with interest. Some of the gentlemen I see here to-night were taking part in that discussion, and I learned a deal of load-line lore. They brought the question home to themselves, made it an individual, personal matter—it took on a vital importance when they urged the necessity of an American registry to fix the load line. I was a good deal bewildered until they removed some screens

at the side of the room. But when they took these screens down and I saw that the load line—the American load line—the American registered load line—was sometimes measured by two fingers, but more often by four-finger depths, then, to paraphrase the words of the Psalmist, "Then understood I those things and the ways of men that go down to the seas." It was most interesting to me to hear these spirited discussions, not only on the load line generally, but on the different lines of load, the individual, personal load line and line of loads, and then I grasped why we must have an American registry of each individual load line and apprehended that, after Admiral Bowles gets the proposition carried through, every one of you chaps will have a two-finger, a three-finger, or a four-finger load line which will allow you to carry a cargo of such fixed nicety that you need not even provide an emergency compartment for water ballast.

After they got through discussing the load line they took up some other matters of vital importance, and something I have heard talked about somewhat called the "freedom of the seas." Some daring mariners took a hand at defining this, which is a subject of effort in many quarters, telling just exactly and precisely what the "freedom of the seas" meant. Now I may say to you that there is a good deal of talk in these days about definitions of the "freedom of the seas" and, being a learned judge of the admiralty myself, I have had some questions of that kind put to me. What is meant by the "freedom of the seas?" Well, gentlemen, "speaking frankly" and using quotation marks when I say "speaking frankly," I have never yet told them what "freedom of the seas" meant. It is a hard thing to define what "freedom of the seas" does mean. I know that Noah had freedom of the seas, for there was no one abroad to interfere with it in his day and generation. But Noah, gentlemen, was the only navigator or trader who ever had the real freedom of the seas. He must have known all about it and what it was and what it was not, but you never caught Noah giving a definition of it and I don't know but that he was right, for if he or any future navigators, even as late as twenty-five years ago, had given a definition of the "freedom of the seas," his definition would not have covered the submarine, and Von Tirpitz could well say, "Ach, your definition doesn't exclude the submarine and therefore the submarine is perfectly lawful." The fact is, gentlemen, I am wary of giving definitions in advance. Now take it in our own business. We have a word in the law called "fraud"—don't anybody get scared about the mention of that subject; I assure you that I am not going to say anything of a personal nature—but we have a word "fraud" and for two hundred years some people, people who had a keen interest in the subject for various reasons—have been trying to get the judges to define what "fraud" was, but the judges were a little too wary to define "fraud," because, gentlemen, if you ever give a chap a definition of "fraud," then he will try to do something that will get a little bit outside of the limits of your definition. No, we were too much on our job to define "fraud." We judges say to the chap, "You go on and do whatever you please, and when you get it done we will tell you then whether it is fraud or not."

What is this "freedom of the seas?" Well, it is a sort of "go as you please," "free for

all." It is the freedom that Germany had during times of peace to push her prows into every port of every nation of the world, which she exercised, without let or hindrance, and in war, "freedom of the seas" consisted of Germany's absolute right to push the prow of her navy out of their hiding places on the North Sea, a "freedom of the seas" which she did not exercise until she formed that long line the other day that ended up on the coast of Scotland. In all seriousness, my friends, if the most scholastic brain of the century had twenty-five years ago defined what the "freedom of the seas" then was, that definition would not have protected us from the hellishness of the submarine. The best definition of the freedom of the seas Germany got was the "made in Britain" sort, the freedom of the seas that France and Italy learned to value and in the Peace Treaty they will not curtail.

I don't want anyone to think I am not fond of definitions, for I am. The most interesting book I know of—the one that has in it every word that ever was coined; that has ever been used in any other book; the one that changes its subject more frequently than any other—is a book on definitions, which was prepared some years ago by another Noah—Webster, I think, was his last name. But I know when to use definitions and when not to use them. Now some years ago, Mr. Carnegie, feeling that he might commit the crime of dying a rich man, concluded to give several millions of his unearned increment to start a hero fund, so he selected a number of us gentlemen in Pittsburgh to go into the business of making heroes. It was a novel enterprise, and we had some very scholastic gentlemen on our board who insisted that before we went into the hero business we must define what a hero was. They said, and with a good deal of plausibility, that we could not award medals and money and go into the hero business unless we had a clean-cut definition of what a hero was. So the whole commission started in to define what a hero was, and I have an idea, from some of the efforts that were made, that if we had waited to get a hero actually defined we would still have been engaged in the phantom definition search on which we started. But, when Mr. X sent in a definition which dispensed with sesquipedalian, scholastic verbiage and, descending to the vernacular of the common people, defined heroes as "butters in what gets hurt," we stopped the definition business then and there and got down to the real thing. But, seriously speaking, gentlemen, I want to say that the German nation complained that they had not the "freedom of the seas" and that one of the justifications of their entering upon this war—what they were talking about over there in Germany when I saw and heard them—was that they were denied the "freedom of the seas."

"Freedom of the Seas!" What is the "freedom of the seas," after all, in time of peace, but the right of any man or any nation to take his ship, with the flag of his nation aloft, and go into any port where he wants to trade and come out freely? Whoever heard of the "freedom of the seas" being denied to the Kaiser or to any one of his ships, or his empire? Who has stood over there in Hamburg, the home city of those great German lines, and watched the great kaleidoscopic map with those little German flags changed every day, telling that German vessels all over the globe were poking their prows up the Yellow River, into Australia, into Southampton, into New York, into Rio; who can stand here to-day and say that

Germany was ever denied the "freedom of the seas" anywhere in peace? But when war comes, who can deny the absolute "freedom of the seas" to the Navy which is standing out in the open of the seas; who blocks the ports of his enemy and puts his thumb on the jugular vein of his enemy's supplies; that from the time Gideon Wells and Abraham Lincoln saved democracy by a blockade on this side of the Atlantic, and Jellico and Beatty saved democracy on the other side, that America and Britain alike were not availing themselves of the true "freedom of the seas?" That is what the "freedom of the seas" is in war and in peace, but it does not consist in using the paths under the seas in the way that Germany has construed the "freedom of the seas" against us, as a neutral country, before we entered into this war. And what the American Navy has done, and what the British Navy for three long years has done for us, was to settle once and for all time that the "freedom of the seas" is not the submarine murder of German "kultur"—of German definition.

My friends, the American Army needs no one to speak for it to-night. It has spoken for itself, and actions are more eloquent than speech. No one ever doubted what the American Army would do when it reached the other side. It came, and it came at a time when it was sorely needed, and no more just estimate was ever made of it than that spoken by a Frenchman to an American friend of mine in France, when he said: "The American soldier combines the dash of the French Poilu and the bulldog of the British Tommy." Yes, gentlemen, the union of the French Poilu, the British Tommy, the American Doughboy—the union of the Tricolor that, mark you, has only the red, the white and the blue in it—the union of the British flag with its three crosses and its three colors of red, and white, and blue—and when we take these men and these colors and join them under that three-colored banner up yonder and put that banner in a khaki suit and over a heart that has the dash of France and the "back against the wall spirit" of Britain, then, gentlemen, you have that for which I speak to-night, THE AMERICAN ARMY; and these three have already, without any signed papers, without any definitions, formed a league of nations that, whatever may be done later, constitutes the league of nations which will stand for all time, for the "freedom of the seas," for the freedom of men, for the freedom of democracy. I want to say also that the men in khaki from this side of the water and the army mule would not have reached the other side had they not ridden on the navy goat to get across the waters. I lay my tribute at the feet, sir, of the men whom you, Mr. Secretary Daniels, represent, and there is nothing that the American people and the world are more justly proud of than the quiet, efficient, unadvertised, night-and-day service of the destroyers and warships that guarded these convoys as they took our boys to the other side, virtually without the loss of a man. The safety of the Army overseas is a great tribute to the American Navy and it is only to be equalled by the great tribute we owe forever and a day to that other great bulwark that during four years has been defending us, which Admiral Capps told me three years ago we could absolutely depend on, and that is the bulldogs of the British navy.

My friends, we are standing to-day in a position which makes many of us feel anxious as we look on the days ahead, the settlement of the great problems, the demobilization of

the men who are on the other side and in the cantonments of this country. The return to normal conditions involves great economic and statesmenship questions that in some respects are even greater than the test that came to us in the rapid preparedness for this war. Then overyone was keyed up with a desire to help and to forward this great patriotic service, but the time of strain has passed and we are tempted to weaken a bit now in our further patriotic service. You can feel it in the air. You can feel it in yourselves, and yet in my judgment we are facing the mightiest of the problems in a return to a peace basis. But in facing that return and that readjustment, there is one great factor we are going to have, and that is in the awakened souls of the 2,000,000 boys in khaki who crossed the seas, or remained on this side, ready to cross, for I make no difference between the man who crossed, from the buck private up to John Pershing, and the man who did not cross, from the buck private to Leonard Wood. For, mark you well, "they also serve who only stand and wait."

These 2,000,000 men are a tremendous added asset to the stability of this country, to the solution of its great problems when they come back to civil life. It has been my privilege to mingle with these lads in the cantonments and drink in their spirit of splendid self-sacrifice to the highest ideals of government. I have found a changed spirit in the souls of men who by education and environment were conscious of duty, and a changed soul in the minds of men who were inspired and ennobled in spite of the humbleness of their origin and lack of opportunity in their earlier life. When they come back they are going to look us through and through; they are going to put an X-ray into our souls. As they themselves have been looking into the souls of men and nations over there that have been purified by four years of conflict, they are going to see when they come back whether we on this side, who have remained at home—we have not had the four years of soul purification—are now, and in the future, to ring true to the higher standard of patriotism and love and duty to country they have learned overseas. And when they come back they will see to it that the same principles, the same ideals, the same rising of soul that has inspired the men in the trenches of all nations over there, are going to inspire them when they return and be the great leaven in the solution of the problems we face.

I wish I might take time to dwell seriously on that subject, but I cannot. I do want to say that in my judgment the principles of Anglo-Saxon law and order and obedience and stability of government have been tremendously increased over all this country by the lessons of order, competence and executive work America's young men have learned in, by and for the Army. The getting the point of going "over the top" and the enduring of hardships without complaint, with a smile on their faces, and with a spirit that, after all is said, it did not matter much whether the tombstone at a man's head made his age read ten years more or less so long as he had done that which is called by the plain old Saxon word "duty"—thank God, I learned it at my mother's knee—"to do my duty in that state of life into which it hath pleased God to call me."

That is the spirit of the Army. Duty is what has been before every man in Belgium, Italy, France, Britain, the colonies, and in our beloved country. Duty! Duty!! Duty!!!

That is the sum and the substance of the soldier's life. Orders obeyed. The laws enforced. Character deepened. All have their center in that single word, "Duty!" And, my friends, what the Army has done for these lithe-limbed, clear-eyed, frank-speech boys, these months of government of the Army, by the Army and for the Army again aided to give government of the whole people, by the whole people, for the whole people to the whole world.

THE TOASTMASTER:—It was quite patent to me when I met Judge Buffington last night that he could do exactly what he has done, and I tender to him not only my personal thanks, but the thanks of The Society of Naval Architects and Marine Engineers.

The next toast is one which we always receive with enthusiasm—"Our Navy"—and with this toast I ask you now to couple the important corps forming a part of our Navy, the corps that at Chateau-Thierry drove back the advancing Huns and became the saviours of Paris—Our Marine Corps. Tennyson's lines paraphrased come to our minds:—

When can their glory fade?
Oh, the wild charge they made!
All the world wondered.
Honor the charge they made!
Honor our Marine Brigade,
Noble few hundred!

To these sentiments I ask the Secretary of the Navy, Hon. Josephus Daniels, to speak.

ADDRESS OF HONORABLE JOSEPHUS DANIELS.

Mr. Toastmaster, ladies and gentlemen, I think it was in keeping with a profound sense of national gratitude that, at the opening of this dinner, which will be remembered as the Victory Dinner of this Society, your President, with a realization that it has come to us, not only by force of arms, but by force of spirit and faith, should have asked us all to sing, "Praise God from Whom All Blessings Flow," and the good minister should have prayed for the day near at hand, the day that has dawned, when peace and righteousness cover the earth like the waters cover the sea.

Last Monday was the day which will be remembered long, and with more pride than any day in America except Independence Day, the day that brought to all the world the light of liberty and hope and gave to weak nations the certainty that every nation anywhere, weak and strong alike, could stand upright and be free. (Applause.) When the soldiers of this great republic landed in France, the people of that country, the people of France, were reassured and were comforted; and somehow or other, ladies and gentlemen, though few of us trace our lineage to that "gentleman of nations," all of us have a tenderer love for France than for any nation on earth other than our own. I think it was Benjamin Franklin who said "Every man has two countries—his own and France."

When our soldiers arrived, they were welcomed with a loving hospitality that warmed their hearts, for the French people thought of them, not that they were soldiers fighting for something for themselves, not that they had gone into war in defense of their fatherland, but that they were crusaders who had crossed the sea that the world might enjoy the same liberties which had been vouchsafed to us here in America. (Applause.)

The sweetest recollection of those days, as the years go by, will be that from first to last the men who represented America, and put their lives in jeopardy, and sealed their faith with their blood that from the day the first soldier went into the trenches of France until Monday last at eleven o'clock when fighting ceased—they behaved as crusaders, as chivalric soldiers, and now that the end has come we can truly say there is not a stain upon their escutcheon. (Applause.) They fought with the eyes on their watches until the hands pointed at eleven o'clock. They fought without quarter, asking and giving none. But when that hour, the hour that will be ever memorable, had arrived, they ceased firing, drove down stakes, dug themselves in and walked across the lines with no hate in their hearts for the men they had conquered. We should look back upon the courage of our men, their victories, their sacrifices, with thanksgiving that they are of our faith and of our blood; and we will be prouder and prouder as the years go by, knowing no vengeance or passion touched the hearts of American soldiers and American soldiers at home (loud applause), and because at home we kept our hearts in tune with the whole impulses of the boys on the firing line.

Not many days before the terms of the armistice had been agreed upon—we call it an armistice; that is the legal name for the complete surrender (loud and prolonged applause)—a detachment of American and French and British soldiers in a bloody engagement captured a number of Germans, whom they took back into the prison camp. Among the prisoners was a young German officer, who had been in America when he was younger. Some of our officers and the French and British officers talked with him about the battles which had been fought, as soldiers always do, and they found that what surprised this young man most was to find so many American soldiers in France. He said to them, frankly: "When I was in Germany a few weeks ago on furlough, I was told there were only a handful of Americans in France, but now it looks to me as if the whole face of creation was covered with Yankee soldiers"—from South Carolina (applause) and from Maine and Texas and California; and one of the things about this war that we have learned in this nation as never before is that soldiers from every portion of it have been proud to be called "Yankee soldiers," and they have all marched to victory to the tune of "Dixie." (Applause.) This young officer's surprise was great, and from that moment he foresaw the end. They talked familiarly about various things, and a French soldier showed him his cross of the Legion of Honor which he had won for bravery and courage, and a British soldier showed his cross, and then he took out his Iron Cross and showed it to them. Then the young German officer said: "I understand all about the Victoria Cross you British soldiers wear, I understand all about the Cross of the Legion of Honor which you French soldiers wear, and about the Iron Cross given to me for courage in battle, but, gentlemen," he said, "pray tell me how did the Americans get a-cross." (Laughter and applause.) You know, and I know, and all the world knows, that more than two million of them got across, because the Navy was on the job, fit and ready. (Great applause.)

War was declared on the sixth day of April, 1917, and on the twenty-third day of April American destroyers were in British waters, and from that day to this—and they have not quit yet, but are there to stay until every term of the armistice is complied with, and there can be no doubt that peace will reign. (Loud applause.) From that day to this, in the cold of winter, the young men on these destroyers, not knowing what it was to sleep in a bed, nor to eat, except to stand up and take a bite at the post of duty—the men on the transports, the men on ships that before the war we thought were almost valueless and which were early commissioned and sent to these hard tasks—there has not been a moment when any duty that was required of the Navy has not been performed instantly and victoriously by them. (Loud applause.) Not only on the seas has the Navy been worthy of the best traditions of the service, but upon the land it has accomplished things so big that never before did a Navy undertake to do them. (Applause.)

I have not time to-night to detail to you these new and striking big things accomplished by men whom I virtually believe, though they have their equals in every profession and trade, as a compact body of capable men have no equal in the world, the men of the American Navy. (Loud applause.) Very soon after this war began, at the request of our

President, Admiral Benson of our Navy (applause), one of the great naval statesmen of the world, visited our allied countries, and in consultation with that brilliant officer, Admiral Sims (applause), took up with officers of the allied navies the things that must be done to stop the submarine menace. It was our opinion that you never could end it except by shutting the submarines up in the North Sea and making it impossible for them to escape to the ocean. We proposed the building of a barrage 250 miles across the North Sea, the greatest undertaking and achievement ever dreamed of by any man in any war in the history of the world. After long discussion and interchange of opinion it was undertaken by the American and British navies, and when the full story of it is written, we will find that it is one of the chief contributing causes of the German appreciation that the day had passed when submarine warfare could be effective against the commerce of the world. (Applause.)

There was another great undertaking, not a naval one, as we understand naval work, but you will perhaps recall that what troubled the allied navies most, after loss of life, was the sinking of tankers. This war has been run on oil and gasoline, and the submarines seemed to have a special talent or evil genius for sinking the tankers conveying the oil essential for the battleships and destroyers. Our naval leaders undertook, in co-operation with the British Navy, to construct a pipe-line, to furnish skilled men to go to Scotland and to construct a pipe-line across the Scottish territory, so that oil needed for the British Navy and our Navy goes through this pipe-line and avoids the danger zone around Scotland. (Applause.)

We all woke up one morning with some feeling of terror when we heard of the German long-range gun shooting into Paris and killing men, women and children. What was the allied need? The need was of a gun, not of that type which, from a military standpoint, was of little value, but of a gun big enough to be an effective weapon in war and shoot far enough to batter even the ramparts of Metz, and the American Navy took its 14-inch guns and put them on trains, carried them into the heart of the country with their ammunition, and were aiding in winning victory along with the soldiers by this firing for a distance of 20 miles of 14-inch guns when the armistice was signed. This is an achievement on land. (Applause.)

These are some of the outstanding things during the war we could not speak of. They were military secrets and of the high lights which show that in this war, wherever there was need for initiative, wherever there was need for resource, something new, something daring, men of the Navy were equal to the emergency, ready to propose and to carry out heroic adventures and practical new accomplishments.

Your chairman has spoken of the gallantry of the marines. There was a time when we had a saying in America, if we heard a story that would hardly go down, "Oh, tell it to the marines!" You have heard that, haven't you? But you will never hear it any more for now they say, "Tell it of the marines!" (Applause.)

The world can never forget that when the German army was almost in sight of Paris, when officials in Paris were packing up the archives, fearful that the city would fall, it was

the second division, half soldiers and half marines, at Belleau Wood and Chateau-Thierry that stopped the onward march and drove the Germans back and gained the initiative that ended at 11 o'clock last Monday. (Loud and prolonged applause.)

It so chanced, gentlemen, not because the marines are any more courageous than the men of the Army—they are all brothers in blood and daring and they were regimented in the same forces—but the impact of the most fearful German "shock" troops was sent against the marines, in the open, and these boys had not been under fire. They were not expecting to go into that battle but, when ordered, they stiffened the lines, turning the tide, drove back the Germans, and out of 8,000, 5,200 were killed, wounded or gassed in the open. The best sharpshooters in the world, they took aim and routed the finest body of Prussian soldiers that ever went against American, or French or allied armies. (Loud applause.)

I wish I could tell you some of the stories I have heard from the lips of these boys. A few days ago I was in New York. I went to the hospital, where some of these boys are convalescing. The boys from Chateau-Thierry had come home, those who were wounded, those who had been so severely wounded that they could not return to battle, and I went there and did myself the honor to pay my respects to them and to take my hat off and uncover and thank God that in the Navy we had such boys in this day of need. (Applause.) I talked to a score of them. One of the nurses said to me—a splendid woman whom I have known for a long time—"I want you to come and see my boy; he is the joy of the hospital," and I went in to see him. He had undergone an operation that had given him great anguish (neither the doctors nor the nurses thought he would come through) but there he was in his rolling chair, red-headed and freckled-faced, the handsomest boy my eyes ever rested on. There was a light in his eye, the light akin to the light that never was on sea or land, and a smile on his face that radiated his room in the hospital, was so contagiously cheerful that it reached the other wards, and made men cheerful, thankful and happy. Of all of them there was not a boy who did not hope that he could be patched up so that he might go back and finish the job. (Applause.)

That is the spirit of all these marines, and the spirit of the soldiers, and the spirit of the sailors. This spirit may be illustrated by an incident related by the nurse. I was told that one of the pals of this boy went to see him, and after talking with him, and when about to take his leave, he said, "Too bad, old chap; it is too bad you lost your leg," and this youngster said—"Why, I didn't lose my leg"—he was in a rolling chair. Said he, "I didn't lose my leg. I gave it." Gentlemen, when soldiers give their legs and lives with such nobility and modesty they are invincible and unconquerable. (Loud applause.)

But I must not detain you with these incidents that thrill and make us proud, all of us, that we have lived in this heroic age. All of us have suffered. Those of us at home who have been on the firing line in sending weapons and ships and everything that contributed to war were of their spirit, and during these eighteen months we have constantly planned, worked and saved in order that the heroic courage of these men might be matched by our spirit of initiative and resource, so that we might give them what they needed.

I came to speak to you to-night, because you gentlemen and the men you represent have from the beginning with vision, with rare vision of the needs of our country, seen that the primal need, the essential need of what we had least of, was ships, and ships, and more ships. It was the neck of the bottle. But for your zeal, your industry, your co-operation, we could not have provided the ships that in the Navy have been so effective, or the merchant ships that have carried food and munitions to our boys across the seas, and I have come here to-night, gentlemen, to extend to you my own thanks and the appreciation of the Government at Washington for the great things you have done, for the spirit you have shown, for the large vision you have had, and for the translation of that vision into the materials necessary to win this war.

We went to war in 1812 for a great principle. We determined that our ships on the sea should have free passage and no sailors' rights should be interfered with by any nation under the sun, and that doctrine we will defend forever against all comers, because it is a primary American doctrine. (Applause.) We fought then for a principle, and though we won the principle for which we fought, and for a generation had free and safe use of the seas, the hour and the day came, fateful to us as a great nation, but a reflection upon the statesmanship and vision of America, when the American flag was rarely seen on the high seas or in distant parts of the world. Senator Hoar, in a great speech, said: "I have seen the glories of art and architecture, and of mountain and river. I have seen the sun set on Jungfrau and the full moon rise over Mount Blanc, but the fairest vision on which these eyes ever looked was the flag of my own country in a foreign land. Beautiful as a flower to those who love it, terrible as a meteor to those who hate it, it is the symbol of the power and glory and the honor of seventy millions of Americans." But he seldom saw it. Our flag was seen almost nowhere and we depended on foreign bottoms for our trade, with the necessary logical result that the ships that carried the trade, of course, gave preference to their own nation. We permitted our mercantile marine to decrease almost to the vanishing point, and as a consequence the American Navy was small in proportion, for Admiral Mahan truly said: "The necessity of a Navy, in the restricted sense of the word, springs, therefore, from the existence of a peaceful shipping, and disappears with it, except in the case of a nation which has aggressive tendencies and keeps up a Navy merely as a branch of the military establishment. As the United States has at present no aggressive purposes, and as its merchant service has disappeared, the dwindling of the armed fleet and general lack of interest in it are strictly logical consequences."

The day is not far distant, I believe, when the American mercantile marine will be a power in the world and carry its freight to every island and land under the sun. (Applause.)

Mr. Schwab, we have just begun to build ships——

Mr. Schwab:—Right, Mr. Secretary.

Secretary Daniels:—We have just begun, and we shall continue building ships to carry our commerce until we have a fair share of all the trade of the world. (Loud and

prolonged applause and cries of "Hear!" "Hear!") Nor shall we live to see, unless wisdom passes from us, the day when the Government will not build ships and operate them. (Applause.) We will carry our commerce, and carry it at prime cost, and deliver it to whoever needs what we produce, whether in South Africa or South America or anywhere else. That must be the policy of a great republic that is to fulfil its mission, develop its industries, and do its duty to itself and to all the world. (Applause.) If we build this merchant marine and conduct it by the Government, gentlemen, we must not shy at the truth that we shall never permit subsidies in this country to be given to ships, because we know that subsidies go to a comparatively few persons and do not create trade; but the Government, representing all of us, will build the ships and operate them for the benefit of America and the expansion of its trade and commerce and the glory of its flag. (Applause.)

And along with that we shall continue the building of a great Navy—a three-year program authorized three years ago will be continued, and another three-year program just like it will be entered upon. We are building 274 more destroyers, costing nearly $400,000,000, and the Administration is determined to press the passage of another three-year bill through Congress; and I have no doubt, before the 4th of March, we will hail its passage as a precursor of our great navy that will make America proud and free and strong to do our part in preserving the peace of the world. (Loud applause.) Nor will we build this great Navy to overawe the weaker nations, or with a thought that we shall use it against nations that, with us, shall go into the League of Peace. One of the propositions, which was a part of the demands of America, was a League of Nations to Secure Peace and to Enforce It. (Applause.) In that League we shall set up a high court, a tribunal, to which every nation must submit its differences, and we must have a powerful, international navy, that will be the policeman of the world and enforce the decrees of this Court of Arbitration; and to that policing America, the richest of nations, which has suffered less by the war than any other great nation, must contribute its part, its large part, so that by this policing of the seas we shall be able to keep the peace of the world until reason and justice may prevail in the hearts of nations without the need of policemen.

Judge Buffington has referred to the great problems that are before us. Gentlemen, we are about to pass from war times to peace times, and many adjustments must be made, but it is the policy of the Government that this transition shall be made easily and gradually—no wholesale cancellation of orders, no stopping of work begun, but to go on with the work, so that factories which have been put into war business may from time to time change, without interfering with their operations, to peace work. We have told the men who are making the big guns that they are to continue to make these guns, but that we will let the guns stand aside for some months in order that they may use their facilities to manufacture goods that shall rebuild France and rebuild Belgium and enter upon new construction and public improvements in our own country.

Have you thought of the demands that will be made upon us to rebuild these countries and to re-establish Russia? As soon as our machinery is in motion and the changes are made,

American business and industry will have so many orders for rebuilding these nations and carrying on the peace work, which for eighteen months has been at a standstill, that we shall find readjustment and prosperity going along together, and continue in this great country of ours.

Gentlemen, there is but one thing we need. We have the courage and we have the ability to win this war and to provide the instruments necessary to win it. No people who could achieve what we have in eighteen months can ever be said to be wanting in the ability in times of peace to carry prosperity to all of the people of this nation, and to make it more prosperous than it has ever been in its entire history. What we need—all we need—is the same spirit of faith in ourselves and confidence in the future. Let us have this faith with work; and we shall see as the months go by and as the years go by, that readjustment and prosperity are one and inseparable, and we shall see that the best days are yet to be. (Loud applause.)

THE TOASTMASTER:—Three cheers for Secretary Daniels!

Three cheers were given with a Tiger.

THE TOASTMASTER:—We have more good things for you. The next toast is "Our Merchant Marine, Now and Hereafter." I asked the Honorable Edward N. Hurley, Chairman of the United States Shipping Board, to reply to this toast, and he consented so to do, but this morning I received this letter:—

"UNITED STATES SHIPPING BOARD,

WASHINGTON, *November 11,* 1918.

"MR. STEVENSON TAYLOR, *President,*

The Society of Naval Architects and Marine Engineers.

"DEAR MR. TAYLOR:—

"On account of recent developments I have been obliged to undertake a mission to Europe and I shall be absent from the country on November 15th. I shall therefore be obliged to forego the honor of being your guest on that evening at dinner.

"I hope you will convey to your members a message of optimism from me. It is my firm belief that the spiritual exuberance with which our people are hailing the news of victory will immediately express itself dynamically in favor of increased production to meet the undiminished but better apportioned demand.

"Very truly yours,

"EDWARD N. HURLEY,

Chairman."

When the speakers not belonging to this Society happen to fail us, as they sometimes do, we call upon our own. I am going to ask one of the four gentlemen that started this Society twenty-five years ago, Mr. Lewis Nixon, to respond to the toast—"Our Merchant Marine, Now and Hereafter."

RESPONSE OF MR. LEWIS NIXON.

Mr. Toastmaster, Secretary Daniels, ladies and gentlemen, and fellow naval architects, we always feel that somewhere in our evening's entertainment at our annual festivities that we should have some little shop talk such as seems to befit a gathering of naval architects. Our president has not, of course, attempted to give you a substitute "just as good," but he has asked me to say something here about the merchant marine, of its past and present, and even to dare to say something about its future.

For more than twenty years I have been speaking on the subject of the merchant marine all over this country. In the past, and during that time, I have spoken of the merchant marine we once had and the merchant marine we hoped to have. Now we seem to feel that we are approaching a time when we can discuss a merchant marine that we have. But when I came to Philadelphia I felt that, if I spoke to the naval architects and those assembled with them, I must speak of a man whose name naturally comes to you as associated with this great city, who has carried the flag of the United States and foreign flags upon vessels built in this city, that have been a credit to the American nation, a man who has probably done as much to keep the American flag afloat and to bring about the sentiment, both for naval shipbuilding and merchant marine shipbuilding, as any man in the entire United States, and that man is Charles H. Cramp. (Applause.)

Our President spoke of the beginning of this Society twenty-five years ago. Admiral Bowles and Admiral Capps came to see me in Philadelphia and we discussed the formation of a Society of Naval Architects and Marine Engineers. I suggested at the time the name of the man who, if we could have him for our first president, I thought would insure a solid and substantial start for the Society upon a field of great and enduring usefulness. I suggested that prince of men, Clement A. Griscom. I did it because I thought that before we began a Society such as this there should be no feeling either of rivalry or bias, as the result of possible misunderstandings, and that we should have some man as president who was, in a sense, away from the actual shipbuilding industry, but a man who at the same time was engaged in the labor, and who later brought it to a successful end, of lifting and carrying the American flag in the Atlantic trade. I saw his son that day and told him what we wanted. He said, "I will cable my father; he is in Europe." The next day the cable came back with the message: "Tell Nixon yes." I sent that cablegram to Admiral Bowles who, with Admiral Capps, was the prime mover in the organization of The Society of Naval Architects and Marine Engineers, and from that day this Society has been a success. Mr. Griscom has been succeeded by competent presidents, men to whom we have looked with respect and appreciation, and who have led us on our way until to-day we have this splendid gathering of naval architects. Even in that time, in that twenty-five years, the achievements

in this country in the way of shipbuilding and ship designing have so ennobled the vocation of those who do plan and build ships, that it abates none of its pride by comparison with any other field in which the human intellect holds sway.

I hope that the young men of this Society will realize we are building shipyards and that there is the place to learn to build ships. Of course we know that the building of a ship makes requisition on practically every other calling, profession and trade. We know that to properly carry out the great project which we have in mind, the enormous program which this war made necessary and which has been so successfully met, means that we should co-operate with every possible means to accomplish our ends; but, gentlemen, I want to say to those who will have to do in the future with the building of our ships and with the planning of these ships that the proper place to learn to build ships is in the shipyards and not in the counting-house or the bridge shop. (Applause.) Yet I think the gratitude of the country should be given to those who have co-operated with the naval architects of this country in building the fleet we have now started. (Applause.)

I am asked to say something about the merchant marine and again, in a sense, have to be personal. I remember in 1885 a very noted newspaper editor of the day said he was asked to edit a new "American Encyclopedia," and he wanted an article on American navigation. Well, he came to me. I knew nothing about the subject practically at that time, but I struggled along and wrote an article. I read the article over carefully several times. In it I had advocated free ships, but after reading the article several times, it did not ring true, so I tore it up and started all over again. I then proceeded to read such history of the merchant marine that I could get hold of, so as to get facts, and I made up my mind, if I were to continue in shipbuilding, that I must know something about the subject. I started in from that time and read every debate that led up to the adoption of the American Constitution, and I read every debate in Congress, either upon commercial laws or upon treaties, up to five years ago. It was quite a task, but I enjoyed it, and I learned a great deal about the American merchant marine.

When this country started the first federalized government, we had thirteen different ways of regulating ships, and every one of them, in a way, interfered with the other, and the compelling cause of the adoption of the American Constitution and the formation of the American Union was to obtain a central power to regulate commerce in the interests of all the people. Naturally, my first thought and first desire was to know what regulating commerce meant, and what was the intention of those great men who wrote that inspiring document, the Constitution of the United States. They must have known what they meant; they were leaders in thought and power and influence in their time, and after the government was established, they took their seats in the Houses of Congress and in the Legislatures of the various states, and obviously the laws they passed must have been such as to carry out the general idea of the constitutional power to regulate commerce.

On July 4, 1789, they passed in the form of a law a Declaration of Commercial Independence, just as they had in 1776 passed a Declaration of Political Independence. They

laid very broad and deep the foundation of an American merchant marine. The Government was not afraid in those days, although only three million in strength, to say to the rest of the world: "We believe that the American shipping upon the seas should be preferred." They did not hesitate to pass laws directly carrying out the power to regulate commerce, to drive trade into American ships, and make shipbuilding and shipowning profitable.

Their first law was such as to give a differential rate both in duty and tonnage taxes in favor of the goods carried in American ships. This extended in several lines and built up the commerce of the United States in all parts of the world, even all the way out to China and back. They confined by tonnage taxes the coasting trade of the United States to ships built in America. They passed also, while looking out for the shipbuilder and shipowner, laws enlightened as any we have to-day guaranteeing to the sailors of the United States better conditions and better food than sailors got on any other ships in the world. What was the result? In a very few years our merchant marine grew, and in a short time we were carrying not only all of our own commodities upon the ocean, but a goodly share of those of the other people of the world, and these laws, as long as they remained on the statute books, kept our merchant marine in that flourishing condition.

In 1815 and 1828, I think due to the machinations—I won't say plots—of foreign statesmen, this situation was changed. Anyhow, possibly due to more cunning statesmanship on the part of the foreigner, we got away from these safeguards that had been established by our earlier statesmen, and from that time on the American merchant marine passed away. We know, of course, that we passed from wooden ships to steel ships, and that we passed from ships propelled by sails to ships propelled by steam, but the contributing cause was cutting loose from the old constitutional regulation of commerce in connection with which two such opposing minds as Jefferson and Hamilton joined hand in hand.

The Civil War practically completed the destruction of the American merchant marine afloat. Many ships passed under foreign flags, and our Government was so shortsighted that it refused to allowed them to come back. We preferred the foreign insurance agent as against our own, and passed laws directly benefiting the foreigner when he sought business in our own country. We have pointed out, time and time again, for years and years, that the United States should insure its own ships, and one of the greatest benefits that has come out of the war is the fact that the United States says it can not only insure its own ships, but that it is a profitable operation for the Government, as insurance could be underwritten at profitable rates.

Our shipping is now growing. We have a good start towards a merchant marine. What kept the flickering flame of American shipbuilding alive since the war has been the coasting trade. We did build ships to go across the Atlantic Ocean, under the initiative of Clement A. Griscom and Charles H. Cramp, ships whose names became household words, and which were superior to the Lucania and Campania, but these vessels have passed away, and yet the St. Louis and St. Paul are making regular trips, and probably making more trips than any other ships we have known to cross the Atlantic.

That was due to the solid and substantial methods of shipbuilding which were adopted by the American people. When they built the first American ships, the Pennsylvania, Illinois, Indiana and Ohio, to ply in the Atlantic trade every shipbuilder in Great Britain, when those ships arrived there, came to look at the boilers and learned boiler making to such a degree that it improved the whole standard of English construction, and many changes followed in order that boiler-making methods should be in accordance with the improved methods adopted by the American shipbuilders.

In 1885 this country was helpless, so far as an efficient navy was concerned. Up to that time the ships in the U. S. Navy were largely made of wood, mournful relics, rotting relics of the glorious past, a shame to the officers who had to serve on them and a joke to those who exchanged salutes with them. Responding to the compelling voice of the people of the United States, we began the upbuilding of the U. S. Navy. At the time we began it we were not able to make the forgings for our crankshafts or gun tubes; we could not make the ordinary composition castings that were needed. Most came from abroad, and so weak-kneed were many of the people of the United States that they absolutely advocated, after we had even built such boats as the Chicago and Atlanta, that in the new vessels we could build the hulls and buy the machinery from the British builders, Hawthorne & Leslie. That proposition was put up to a patriotic Secretary of the Navy and he said in answer: "If we have a Navy under my administration the ships are going to be built, both hulls and engines, of American material and by American labor." That Secretary of the Navy was William C. Whitney. (Applause.)

At the beginning of our new Navy we standardized in steel shapes and gave orders that enabled us to build the most intricate forgings for both guns and machinery. That started us on the right road until to-day we acknowledge no superiors in the art of steel making, and I believe this policy was the foundation of much that came afterwards, not only in the manufactures that contribute to shipbuilding but in respect to the steel industry itself, because this policy warranted our shipbuilders and steel makers in starting and gathering the necessary nucleus for an organization for shipbuilding on a large scale.

One could talk, of course, about the merchant marine as long as the night lasts. I notice the subject, as given to me, also says—"And its future." I think the future is most promising, and I am always anxious to be an optimist. I do not know, however, that we can make a jack-of-all-trades even of a shipbuilder. I think the people who have developed shipbuilding, the men who have started out and organized fleets of ships and brought them to successful operation, must know something about their needs. I do not know that all ships can be alike and give a varied service. I think he would be a brave man who undertook to standardize now, but what we need is to attain our rightful place on the ocean. We are entitled to carry our own products, regardless of whether we get a larger share of the other people's products or not, but whether we can standardize at this time, without a more extended operation, I do not know, and I do not believe anybody else does. Every ship which has been begun is to be finished, of course, and we hope they will all be finished and get into

useful occupation as soon as possible, because there is a demand for them. Just how they are to be handled is a problem, naturally, which would require the strongest powers of statesmanship any country is capable of exerting.

We shall enter into the carrying trade of the world and take our rightful share, which up to the present time we have not had. If these ships are to be controlled by the Government, then it is the most tremendous undertaking of government ownership that the world has ever looked upon. Primarily, ships are built for profitable operation, and if we are to extend the lines and nurse them along to profitable operation, as foreigners have so often done and found that their result was justified, perhaps this Government will indulge in that great task. If these ships are to be given to men, or leased to men to operate, they must be men who are willing to meet conditions as they find them upon the ocean.

We may have to pass new laws. I have given my entire life to the study of legislation as affecting our shipping, and I believe that if we do pass new laws we should also repeal an existing law which was primarily passed to trammel and obstruct the development of the American merchant marine. The sooner you gentlemen realize that now is the time for frank speaking, and that you have a duty before you, the better. You must go forward in your various spheres of usefulness and influence and must use such influence as you possess. If you think the La Follette law as now standing on the statute books of the United States is a trammel upon American enterprise at sea, be men enough to come out and say so and try to have that law repealed. (Applause.)

Now I am looking forward to seeing our flag in every port. It is nothing new. The flag of the United States used to fly in every port under the benefits of enlightened statesmanship, and my hope and desire is, as a patriotic American, that the time will soon come when we shall see that state of affairs reestablished and the American flag flying on ships engaged in useful and profitable occupations in all quarters of the globe. (Great applause.)

THE TOASTMASTER:—Our next toast is "Our Allies." First I give you "Great Britain and Ireland," and call upon you to rise in honor of His Majesty, King George V.

The company then rose, toasted King George, and Mr. Louis J. Winsch sang "God Save the King," the company joining in the National Anthem of Great Britain.

THE TOASTMASTER:—I have in mind a little sentiment that comes with that part of this toast. It is as follows:

"May the rose of England fairer blow,
May Scotia's thistle taller grow;
May the harp of Erin sweeter play,
While the Stars and Stripes shall hold their sway!"

It would take too much time to toast all our Allies, and we will epitomize them all in "La Belle France."

The company then rose and drank a toast to "La Belle France," Miss Irene Law singing "La Marseillaise," robed as Joan of Arc.

The President:—The next toast, gentlemen, is "Our Ships and Shipbuilders." I will call, to respond to that toast, a gentleman who has never shown greater spirit, energy and determination than in these last eight months. He has shown great spirit in shipbuilding, and none can respond better than the Honorable Charles M. Schwab, Director-General, Emergency Fleet Corporation.

RESPONSE BY HON. CHARLES M. SCHWAB.

Mr. Toastmaster, Mr. Secretary, ladies and gentlemen, although the introduction of the toastmaster was an inspiring one for a man who intended to make a true, patriotic and serious speech, I find it very difficult to speak this evening under the auspices under which I start—not only am I last on the program here, but even the good reverend gentleman started off invoking a blessing on every department of the Government and shipbuilding except the Emergency Fleet Corporation. Now, I do not know whether he thought that the Emergency Fleet Corporation did not need it, or whether he thought it was so bad that even his blessing would not help it. I cannot very well understand that point, but notwithstanding that handicap, after listening to the splendid addresses of the gentlemen who followed him, I commenced to feel some spirit of enthusiasm, when that great lawyer from Pittsburgh, whom I have known and been associated with so many years, got up and put the fear of the Lord so into my heart that that which I intended saying I cannot say. Now, Judge Buffington is a mighty fine lawyer, but I am afraid he would make a pretty poor shipbuilder. I do not mind saying that when I came to the Emergency Fleet Corporation he was the first fellow who came down and insisted on a shipyard in Pittsburgh. (Applause.) He is a really enthusiastic Pittsburgher, is this Judge Buffington—he was my lawyer for many years. Mr. Daniels was telling me a short time ago things that I do not like to be reminded of—things that happened about twenty years ago, when water was then a good deal discussed, and not to float ships. I had something to do with things of that kind. I had congratulated myself that I had forgotten all about them, until the Secretary brought the subject up again. Then I thought of an experience about that time with Judge Buffington, when I went to him for legal advice. That advice was of such a character that I went home feeling that I was about the worst culprit in the United States.

I went to sleep and had a dream. I dreamed that I would shrive my soul of all the things that I had done wrong with reference to flotations, and water, et cetera, and, good Catholic that I am, I went to see old Father Hickey. Mr. Morgan, who had been in similar enterprises with me (laughter) was on the other side of the confessional, and the good Father between us, when suddenly the Father disappeared and I saw my friend at the other end. I said:—"Mr. Morgan, where is the good Father gone?" "Oh," he said, "I think he has just gone out into the church." I said, "Don't you believe it; he has gone for a cop." (Loud laughter and applause.)

Well, since those days we have gotten into a respectable sort of business, the building of ships.

I went upstairs at 5 o'clock this evening, very tired as the result of traveling from Boston last night, and thought I would have a few moments' rest. I threw myself down on a

couch and dreamed of the delightful banquet we were to have here to-night. I thought of a meeting we had twenty-five years ago, which I attended. In my dream I saw the few people that we had then, some twenty or thirty, possibly forty, and then I thought of this great aggregation of the shipbuilding talent of the United States here to-night. To me it seemed to be typical of what had happened in these United States to this great industry—that this representative gathering of to-day, as compared with the gathering of twenty-five years ago, is but typical of the wonderful progress which this great business has made, of its wonderful influence upon this nation, and of the wonderful effect it is going to have upon this nation in the future. (Applause.)

I dreamed still further, with a wondering mind, and I saw in my dreams a great procession pass along Broad Street, in this city, by the offices of the Emergency Fleet Corporation. This procession attracted me intensely. In my dream I looked out of the window, and there, at the head of this great aerial procession which was floating past, was the distinguished Secretary of the Navy. He had in his hands and about his person every blooming shipyard in the United States that was worthy of the name. Here was Fore River and here was Union, and so on in the case of every yard that could build a ship; the Secretary of the Navy had them all, and he maliciously dangled them before the faces of the officers of the Emergency Fleet Corporation. Of course this was a dream, and I may not have seen distinctly. He seemed to have under his arms something that looked to me like two beer kegs. I cried out in my dream, "Surely, Mr. Secretary, this cannot be true." "Well," he said, "I am passing the offices of the Emergency Fleet Corporation; Mr. Hurley and Mr. Colby said the proper way to grease the ways was with beer, and I am taking along beer kegs as typical of the fact that if, in floating ships down these ways, beer will grease them better than soap, then beer this country shall have, because we want the ships." (Applause.)

The next man I saw in this great procession as they marched along was Hurley, the chairman of our great United States Shipping Board, and almost all that poor Hurley had was a pick and a pile-driver—the only things that the Secretary of the Navy had left him. Every shipyard was gone, and there was poor Hurley trudging along, supported by Admiral Capps on one side and Admiral Bowles on the other, helping him to carry these things as he had to create in that way the great shipyards of this country, so as to give us our merchant ships.

Well, you know this is a dream, and yet it is not really a dream. It is a fact. In view of the great shipyards that this man and his organization have created, and of all the men in the United States whose names have been mentioned in all honesty and as deserving of real credit for pioneer work in the development of the Emergency Fleet Corporation, what men are there who have gone through the weary trials, and who deserve the real credit, as have Admiral Capps and Admiral Bowles? When history writes the record of the Emergency Fleet Corporation, the names of Admiral Capps and Admiral Bowles will be the brightest among them all. (Applause.)

I dreamed on, and I saw, as I have often seen in my waking hours—but yet this was a dream—I saw a handsome lady, who looked like a prima donna, coming along, and I

asked myself—"Who is that person." She was supported by Holbrook and Baldwin and Webster and Stone and a great galaxy of people, and they said, "That is the great prima donna of Hog Island." She was a lady beauteous to look upon, with a reputation not unsullied by investigation and popular report, but still in such a degree of respectability that she did attract attention. The gentlemen with her—and there were many of them—were surrounded by a guard of honor of some seven or eight hundred splendidly uniformed and mounted policemen—she needed that protection in Broad Street—this great galaxy was wending its way through the street, every one asking who she was, what she was, and what she was going to do. Well, gentlemen, Hog Island is all right, notwithstanding that dream, and I am going to tell you some of the real truths about her a little later. As to the lady who posed so beautifully and looked so well, I am not going to tell you about her now. I will tell you later.

Then I saw a number of men approaching, fine looking fellows, Joe Powell, Holbrook, Kneeland, and a lot of other fellows, and I thought, "What have those fellows in their hands, they look so fine," because each one carried a big chart in his hand, a chart to show the people what they were going to do. (Applause.) Boys, that was the most magnificent set of charts I have ever seen.

Then there came another distinguished man in this procession that commenced to look like a Roman fête. It was Admiral Bowles, dragging a cow by her tail. The admiral was then explaining that this cow had to go. He said that he could not make her go forward, but he had promised to make her go, and therefore he was obliged to drag her through the streets. (Laughter and applause.)

So my dream went on, and I saw an aggregation of people representing all the various branches of the Emergency Fleet Corporation file by. Then I woke up with a start, with the realization, Mr. President and Mr. Secretary, of the real facts—dreams often go by opposites—and instead of the recital at which you have laughed, which was a fantasy of a brain in sleep, there came to my view a magnificent fleet of some six or seven hundred merchant vessels that these gentlemen had built in the last year, with the American flag flying proudly from their prows. (Loud and prolonged applause.) I thought to myself, what a splendid awakening and what a splendid return to a former state for this great country, and what credit these craftsmen and shipbuilders of the United States deserved. They have made history for themselves, Mr. Secretary.

In the shipbuilding industry we have our traditions, too. You spoke of the traditions of the American and other navies, Mr. Secretary. We all take our hats off to these traditions and things of the past, but I would have you all know that the Emergency Fleet Corporation has a tradition for itself far back of anything you have ever dreamed of, Mr. Secretary. Why, Noah was the first man to build an emergency fleet. Our history and our records and our traditions go gack to the time of Noah, and I challenge the Army and I challenge your Navy, Mr. Secretary, and any other navy in the wide world, to show a tradition as ancient and as honorable as the Emergency Fleet Corporation.

Now, gentlemen, just to be serious for a moment. I am going down to White Sulphur

Springs in a day or two for a rest. I have had eight rather strenuous months. I have had to associate with Piez and Page and the rest of them and I am almost tired out. I am going down there for a little rest, and I hope you will not tell any stories on me upon my return as Replogle told them on me in New York once when I was away. He came over and said, "I saw C. M. at White Sulphur Springs," and the friend asked, "Was Grace with him." Replogle replied, "Well, I don't know her name, but she was mighty good-looking." (Laughter.)

I am going down there with a sense of satisfaction, a sense of thankfulness, and a sense of appreciation that I can ill express in any words I might choose. My association, Mr. President and Mr. Secretary, with these gentlemen who are directly responsible for building ships in this hour of the country's need has been, indeed, a splendid association, and one that must make everybody feel that the highest type of American manhood and patriotism and energy has been centered in the shipbuilders of the United States. (Applause.) They have done their part and done it nobly; they have worked under the most trying circumstances and with the greatest disadvantages, with a cruel winter last year (we have had none like it for many years) which delayed us many months, with a shortage of labor, and with new management and new work. It seemed to me that the conditions were such as to make large production well-nigh impossible. Yet, gentlemen, you will be glad to know that in the month of October we produced 410,000 deadweight tons of ships, and I think in the month of November we will pass our best prophecy of over 500,000 tons of ships. (Applause.)

Now, under all the conditions which have existed, this organization, this Society, so largely represented by the builders of ships, is to be congratulated. As far as I am concerned, they not only have my sincere thanks, but they have my admiration—yes, they have my love for the loyal and splendid manner in which they have co-operated and for the way in which we have carried through this program. I have had nothing but the best service from every source. Troubles, of course, we have had. What great business does not have its troubles? But they have all been overcome and every one concerned has been filled with enthusiasm, and, Mr. President and Mr. Secretary, while we have been spurred on with the patriotic influence of endeavoring to supply our boys across the sea and have had all the pleasure that patriotism brings in the accomplishment of such a task, the real pleasure to us now is to know we are building ships that will transport to their homes and their mothers' firesides boys that bring with them the victory that has made this great country what it is. (Applause.)

We built as a work of necessity to date; we now build as the work of love until we have brought these boys home, and how proud we should feel of them all. Is there one heart in this room that was not stirred by the Secretary's description of what these boys have done? It is not the men who have built ships, however well and nobly their duty has been performed; it is not the boys who have made aeroplanes and guns, or anything else in the service whose names will be written on the golden pages of history; but it is the boys who were in the trenches of Flanders, who have risked their lives, and in many cases made the supreme sacrifice, for their country, that deservedly shall have their names in our hearts, in our mem-

ories, and on the golden pages of the glorious history of this country. I thank you. (Loud applause.)

THE TOASTMASTER:—First, I want to express in your behalf, gentlemen, the thanks of this Society and its guests to the Local Committee, Mr. William Griscom Coxe, Chairman, and Messrs. Henry A, Magoun, Joseph N. Pew, Jr., Richard H. M. Robinson, H. Birchard Taylor, and F. W. Wood, for these gentlemen have produced the setting of this magnificent function. Then I wish to express, as is usual and most proper, our thanks to the secretary and his assistants. Finally, I want to introduce to you the President-elect, Rear Admiral Washington Lee Capps. (Great applause.)

ADDRESS OF PRESIDENT-ELECT WASHINGTON L. CAPPS.

Mr. Chairman, Mr. Secretary, our distinguished guests, ladies and gentlemen, fellow-members, we have a tradition in this comparatively young Society which bids us not to attempt too much early morning work. So, in view of the hour, you need not be alarmed at the possible length of time I will detain you.

This Society owes much to the city in which we are holding our "victory" banquet. In fact, it was here that it was born. It also owes to Philadelphia its first president, that gracious and distinguished gentleman to whom allusion has already been made, Clement Acton Griscom. And now we are having in Philadelphia our twenty-fifth anniversary meeting under circumstances which I need not describe,—you all know how felicitous they have been,—and this is by all odds quite the most successful annual banquet we have ever had.

Our first president, in his inaugural address, said that he accepted the honor of the presidency, not as a personal tribute but rather as a recognition of the important interests over which he presided and which were so intimately connected with the art of shipbuilding. May I follow his lead, and, in all seriousness, say that I accept the tribute you have paid me in electing me as your president, not as a personal one but rather as a tribute to the profession which we all love, and to the naval branch to which I have the honor to belong.

But with your congratulations and good wishes I must ask your sympathy and help. From this time on this Society is in danger of dwelling in the clouds and becoming a dreaming branch of the aviation service. So many complimentary things have been said to-night about shipbuilders and naval architects, and the dreams so graphically described by our fellow-craftsman, Mr. Schwab, are so entrancing that I am very much afraid our members may try to navigate the skies instead of keeping their feet on this good old earth or sailing the seas in ships. So please bear in mind that for the next year my main task may be to keep you from flying. But I know you will obey and do your duty, as you have always done it.

Now, gentlemen, for the real purpose of my arising to say anything. The success of this Society has always been due to the devoted efforts of its members, and particularly of those who have presided over its destinies from time to time. Your retiring president has had the unusual distinction of holding the office twice. Our constitution does not permit a president to succeed himself, but there are ways in which we can get two terms out of one presiding officer, so that Commander Stevenson Taylor has been twice elected to the highest office in your gift. On the occasion of the completion of his first term of office his colleagues of the Council of the Society presented him with a silver souvenir. On this occasion they have given him the privilege of subscribing handsomely to our Endowment Fund. So, you see, he is a man dear to all our hearts—one who always appropriately responds to whatever occasion may arise. Now that he is about to relinquish the cares of office, I wish to be ac-

corded the very great privilege of joining with you in acclaiming our retiring president, and showing our appreciation of the continuous and splendid work he has done for this Society, and, through the Society, for our whole nation. Gentlemen, I ask you to rise and express your regard and esteem for our retiring president, Commander Stevenson Taylor.

The entire company arose, amid great applause, and gave three cheers for Commander Taylor.

President Taylor:—Admiral Capps did not tell you the whole story of the Council meeting on Wednesday. He only mentioned the small part I played in it. He tried to initiate about four years ago an endowment fund for this Society that would eventually grow to afford a sufficient sum so that we could do what we desired in the way of giving prizes, the entertainment of foreign guests, or what not, that might arise, which would otherwise involve an outlay for which individual subscriptions would have to be solicited. That scheme fell upon bad times—the war broke out, and shipbuilding fell down to 225,000 tons a year instead of 500,000 tons a month, and the matter was postponed until last Wednesday, at the Council meeting, when Admiral Capps brought up the subject again. We found that we had, by a ruling made a few years ago, about $18,000 already in the endowment fund, so he asked the members of the Council to make that at least $25,000, and they did that right on the spot. They have not asked any member outside of the Council for any contribution; your turn will come some time in the future. That, it seems to me, illustrated the deep thought and great interest in this Society that Admiral Capps has held for so many years, and I want to say that no other one man in this Society has given it so much personal, careful consideration. That is not known to the members at large, but is known to me, who have been close to him all these years—no man has given so much thought, which has been so well directed and borne such fruitful results in the advancement of this Society, as Washington Lee Capps. (Applause.)

And now, gentlemen, I have two or three words of thanks to say to you all. I have enjoyed the work as president of your Society. Having worked particularly hard recently, I am naturally glad now to be relieved, but I will never lose my regard for this Society. I will never decline to do anything I can to advance its interests and I will always hold in my heart charming memories of the very many, many friends I have made, friends that still stand by me to the end. (Prolonged applause.)

This meeting is adjourned.

The company then dispersed.

Deaths, 1918

HARRY B. BLOOMSBURG

ASSOCIATE

THE RT. HON. EARL BRASSEY, G.C.B., D.C.L.

HONORARY ASSOCIATE

The death of Lord Brassey marked the passing of a man full of years and of high esteem. He was one of many who contributed so largely to the strides made during the last half of the nineteenth century. To us he will be best remembered by his contributions to and interest in all that pertained to the sea. A study of his life reveals, however, that his activities were many and his usefulness great. He was a charter member of our sister society in London and throughout his life contributed to its proceedings, besides serving on the Council and later as president.

The late Earl Brassey was born in 1836, being the eldest son of Thomas Brassey, the great railway contractor, among whose many works were part of the Southwestern Railway and the first railway to be built in France, connecting Paris with Havre.

He was educated at Rugby and University College, Oxford, where he took honors in Law and Modern History. In 1861 Lord Brassey (at the age of twenty-nine) unsuccessfully contested the parliamentary borough of Birkenhead in the Liberal interest. Four years later he was elected member for Devonport, and sat for a few months until the dissolution of Parliament. The following year, at the general election, he was defeated by a narrow majority as candidate for Sandwich, and in 1868 was elected for Hastings, which borough he represented continuously for eighteen years. From 1880 to 1885 he served in Mr. Gladstone's Government, first as Civil Lord of the Admiralty and afterwards as Parliamentary Secretary of that department.

In 1882–3 Lord Brassey published a comprehensive work in five volumes

on "The British Navy: Its Strength, Resources, and Administration," which dealt with the material side of the navy, its ships, its dockyards, and its seamen. So great was the value of this publication that the author decided a few years later to issue a Naval Annual, and this publication, edited first by him and subsequently by his son (The Hon. T. A. Brassey, afterwards Lord Hythe), has now become a standard work with which his name will always be connected. The Navy Annual includes particulars not only of the British but of all the principal foreign navies, and upon it have been modeled numerous similar publications at home and abroad.

The "one clear call" which, above all others, predominated in his versatile nature was undoubtedly the call of the sea. From earliest boyhood it had exercised its fascination upon him, and when in later years the opportunity arose for yachting on the grand scale, it was the Sunbeam that became, not only his floating home for many a long and happy month and the nursery of his children's early years, but it was the means of gratifying that love of travel and adventure which he shared with all the members of his family. The yachting habit had, however, been acquired long before the advent of the Sunbeam on the scene. As far back as 1855, while still at Oxford, Lord Brassey had successively owned two cutters, the Zillah and Cymba, in which the first lessons of the sea were learnt with all the enthusiasm and glamor of ambitious youth. Next followed the Albatross, an iron-hulled schooner of 120 tons, in which a voyage to the Mediterranean was undertaken with not entirely happy results; for the prevalence of adverse winds and the difficulties of navigation, unaided by steam, were such that no further ventures were made in pure sailing yachts. It was at this time (1859) that the proud owner of this 120-tonner was elected to the Royal Yacht Squadron, of which he lived to be the oldest member. After the Albatross came the Meteor, a good-sized auxiliary schooner in which he undertook, as his own master and pilot, the difficult navigation to the Baltic, until the fogbound coast of Sweden made the services of a pilot indispensable. Lord Brassey was the first amateur yachtsman to obtain by examination a Board of Trade master's certificate, and it is a proof of his undaunted courage, not unalloyed with some of the rashness of youth, that he forthwith undertook a task from which many a more experienced master might have shrunk.

The classic "Voyage in the Sunbeam Round the World" (1876–7), by Lady Brassey, which was translated into nearly every language in Europe and reached an enormous public, tells its own tale of voyage and adventure, and brought a rich reward of experience and of lasting friendships. Tangible records were seen in the collections that soon grew into a veritable museum of souvenirs, of produce and workmanship in the hospitable mansion at Park Lane and the spacious rooms of Normanhurst. In both these homes Lord

Brassey delighted in showing to all and sundry the treasures that had been thus brought together, and with a charm of manner which all who knew him will recall he would make the glass cases tell their own tale of far-off lands and bygone times. His final presentation of the Sunbeam to the Indian Government as a hospital ship in the second year of the war (March, 1916) was a happy and generous token of unselfish patriotism. No more fitting use could have been found for the later days of that noble ship, whose long record of 500,000 nautical miles under sail and steam, in fair weather and foul, was one of which he was justly proud. In a volume published only last year the life story of this famous ship was again given to the world as a fitting sequel to the earlier work by his first wife.

Coming as he did from a stock that had, by sheer hard work and enterprise, successfully carried through great public undertakings, Lord Brassey fully realized the importance of the part played by labor in the development of a nation's resources. "Work and Wages," which he first published as a sequel to the biography of his father by Sir Arthur Helps, was reprinted in later years with additions dictated by matured experience. The welfare of the working classes and the share to which they are entitled in the profits due to increased efficiency and output were strongly advocated in "Work and Wages." "From the inexhaustible fountain of labor," he wrote, "springs all that constitutes the wealth of nations." The case for labor could not be put more strongly or concisely. The eternal "labor question" which confronts our industrial community constantly engaged his thoughts and attention, and many were the addresses which he gave on these social problems and their solution. The broad views of a mind fitted by nature to touch the sympathy and understanding of his fellow-men were a good foundation upon which to build in setting out to solve these thorny and difficult problems. Towards seamen in particular his sympathies were drawn by the common bond of sea service. The bluejacket, the man before the mast, the yacht hand, and the fisherman were to him all fellow-craftsmen whose outlook on life could be appreciated because it was understood.

Lord Brassey was long impressed by the want of system in the training of boys for the position of officers in the mercantile marine. Education in stationary vessels such as the Worcester and the Conway having come to an end, boys had to pick up their practical knowledge as best they could in seagoing vessels of all kinds. Being convinced of the desirability of giving the boys further education and systematic training on board ocean-going sailing ships, Lord Brassey, with this object in view, inaugurated a scheme in 1890 in conjunction with Messrs. Devitt and Moore, becoming part-owner of the Hesperus and Harbinger, large vessels trading to Australia. On board these ships, and others subsequently acquired, hundreds of cadets have for many

years past been carried, the greater number of whom, after acquiring a good preliminary knowledge of seamanship and navigation, have passed the Board of Trade examination and obtained berths in well-known liners.

Lord Brassey's death was suitably recorded in the 1918 Transactions of the Institution of Naval Architects and our résumé of his life's activities was taken from this authority; for a record of his services to his country and our profession it would be hard to find a more satisfactory source of information.

Lord Brassey's connection with this society dates from the year 1895, when he was elected an Honorary Associate by the Council of the Society.

One by one the men who made the last half of the last century the notable one it was are passing away, and we are proud to render our homage to them as they pass to the Great Beyond; to none can this homage be more justly paid, the knowledge of his life's work cannot fail to inspire.

GEORGE W. DICKIE

VICE-PRESIDENT

A leader of the profession passed away with the death, on August 16, 1918, of George W. Dickie, one of the Vice-Presidents of the Society. He was born in Arbroath, Scotland, July 17, 1844. After the usual education in elementary schools, his professional training was obtained in his father's shipyard and in the offices and shops of the North British Railway.

He came to San Francisco in 1869, and from that time until his death was a prominent figure in engineering matters on the Pacific coast. He designed considerable machinery for the mines of the Comstock Lode and became manager of the Union Iron Works in 1883, holding that position until 1905. As will be noted, this period covered the birth and growth of the new navy of the United States, and in this work Mr. Dickie played a prominent part. Two of the ships turned out by him, the Oregon and the Olympia, will long hold a leading place in the memory of those familiar with naval affairs, but they were only two of a great many vessels built for the Navy.

Mr. Dickie was thoroughly grounded in all the details of the profession,

and under his management the work turned out was of a remarkably high class. The writer of this sketch served on one of the Union Iron Works vessels, and can testify to the splendid workmanship on the machinery of that vessel. The writer also was told by Chief Engineer Milligan of the Oregon, the man who made her famous, that his task was rendered much easier by the splendid workmanship which had been put upon the machinery of that vessel.

Mr. Dickie was an original and courageous designer; and the pages of the Transactions have been enriched by the papers he contributed. He had been president of the Technical Society of the Pacific Coast and a member of the Council of the American Society of Mechanical Engineers, as well as a member of the Council and Vice-President of our own Society. Mr. Dickie inspired confidence and respect in all who came within the circle of his influence, and was a highly valued friend of those to whom he gave his confidence.

The Council and Members of The Society of Naval Architects and Marine Engineers in convention of this date, taking note of the death of Mr. George W. Dickie—

"*Resolved,* That the Society desires to record its sorrow at the death of one of its Vice-Presidents, who was a leader of the profession and who had always taken an active interest in the Society.

"*Resolved,* That we tender to his family our sincere sympathy in their great loss, and that we assure them of sharing in their pride in his splendid record of professional achievement.

"*Resolved,* That these resolutions, with the accompanying notes of the career of Mr. Dickie, be inserted in the Transactions of the Society, and that a copy be sent to his family."

STEVENSON TAYLOR,
President.

DANIEL H. COX,
Secretary.

November fourteenth, 1918.

CHARLES R. HANSCOM

MEMBER

ROBERT LOGAN

MEMBER

Mr. Logan was born in Glasgow, Scotland, March 14, 1861. He was a graduate of the University of Glasgow and of the College of Science and Arts, Glasgow, winning the Queen's Prize for mathematics at the latter college in 1882.

After graduating he became chief draftsman for the shipbuilding firm of Mansell & Aiken, Glasgow, Scotland.

On June 14, 1888, he came to Canada as Superintendent of Construction of Vessels for the Canadian Pacific Railway, locating at Owen Sound. After a number of years he opened an office with A. O. Rankin at Toronto, Canada, under the name of Logan & Rankin, as naval architects and marine engineers.

He came to Cleveland, Ohio, in 1903, as general manager of the American Shipbuilding Company, which position he held until his resignation in 1910. Since 1910 Mr. Logan maintained an office in Cleveland, Ohio, as consulting engineer, which he operated until his death.

Mr. Logan designed many of the largest freighters on the Great Lakes and was considered one of the ablest men in his line in that section.

Mr. Logan was a Thirty-second Degree Mason, Mystic Shrine, Scottish Rite, and was also a life member of the Benevolent and Protective Order of Elks.

He died in Cleveland, July 25, 1918.

COMMODORE GEORGE W. MAGEE

MEMBER

Commodore George W. Magee (Commander, Engineer Corps, U. S. Navy, Retired) passed away December 8, 1917, at East Orange, New Jersey, amid the sincere regrets of a very large number of friends. He was born in New York City, February 1, 1840, and so was almost seventy-eight years of age at the time of his death.

Commodore Magee was one of the fine products of the old order of marine engineers who may be said to have trained themselves, because in their early days there were few schools of engineering, and none of marine engineering, in this country. After the usual training in the public schools, he

became an apprentice in the pattern shop of the Novelty Iron Works. He had great natural aptitude as a mechanic and engineer, soon became a skillful pattern-maker, and was promoted to the draughting room when he was eighteen. During his service in the draughting room, his talent as a designer had opportunity for development, and he had made the designs for important machinery before he was twenty-one, including the Pacific Mail Steamer Constitution, the largest vessel of that line. One of his contemporaries, in speaking of work done by him, credits him with designs for an overhung cylinder for stationary engines years before it became a common thing, and also the design of piston valves at an early date. He was also confidential assistant to Mr. Horatio Allen, president of the Novelty Works, making drawings, models, etc., for inventions and experiments.

While he was at the Novelty Iron Works they were building certain machinery under the supervision of Admiral Isherwood, then a chief engineer. The latter was impressed with Magee's ability and advised him to enter the Navy. Magee passed the entrance examination in November, 1860, and before the breaking out of the Civil War he entered the Navy as a third assistant engineer, April 4, 1861. Incidentally, it may be remarked that this was the beginning of a friendship with Admiral Isherwood which lasted unbroken until the latter's death.

Knowing Magee's ability as an engineer and designer, Isherwood, as Chief of the Bureau of Steam Engineering, had him detailed to that bureau, where he rendered excellent service in working out the designs of some of the famous machinery which has become so well known to all engineers through Isherwood's "Experimental Researches in Steam Engineering." His first efforts were in connection with the completion of the designs for the machinery of the Pensacola. He went to sea in that vessel and took part, under Farragut, in the passage of the forts below New Orleans, April 24, 1862. Later he resumed duty under Isherwood.

Commodore Magee served as an assistant engineer and as chief engineer on numerous vessels of the Navy, ending with the monitor Miantonomoh. He was washed overboard from the deck of the Miantonomoh and barely escaped drowning. The result, however, of the exposure was a heart affection from which he never fully recovered, and he was retired in June, 1893. He was detailed at the New York Navy Yard, the Continental Iron Works, and other places on shore duty; but that which perhaps gave him the greatest satisfaction was as a member of the Experimental Board of Engineers, of which Admiral Isherwood was the president. This board conducted a great many very valuable experiments, the results of which were published in the Annual Reports of the Bureau of Steam Engineering. Many of these are

now classics, having been conducted with Isherwood's extraordinary skill and care, and furnish a source of information to which engineers constantly recur.

Notwithstanding his retirement, Commodore Magee retained his interest in engineering matters, and even towards the last of his days was planning improvements. The writer remembers a design which he submitted in his own beautiful draughtsmanship to the Navy Department for a protection to the base of turrets of our dreadnaughts. Incidentally, it may be remarked that he had preserved many of his drawings made in early days and recently presented them to the Engineering Department of Webb's Academy.

Commodore Magee was a man of charming personality and had the social instinct, so that he maintained touch with all his old friends and was constantly making new ones. He was a member of the Engineers Club, where he frequently lived in the winter time, and was always a welcome addition to any group of members. He was a member of the Loyal Legion and took a very active interest in its affairs. He had been a member of our own Society from the very start and rarely missed one of the annual meetings. He was so well preserved that it will probably be a source of surprise to many who did not know him well to learn of his great age.

What proved to be the last important act of his life had to be finished by others, on account of his last illness. As already stated, he had been a great friend of Admiral Isherwood, and, indeed, might be said to have been a worshiper. He had secured an admirable bronze bust of Isherwood and had arranged for its presentation to the Society of Mechanical Engineers at their meeting in December, 1917. His address of presentation was prepared, and everything ready, when he was stricken with what proved to be his last illness; and what would have been one of the greatest pleasures of his life devolved upon a younger engineer, also a devoted admirer of Isherwood, who read the commodore's address, supplementing it with a few remarks of his own.

Commodore Magee occupied a very warm spot in many hearts, and as he had constantly mixed with younger men, who all were very fond of him, it will be many years before his memory has entirely passed away.

FRANK SERVICE MASTEN

ASSOCIATE

Mr. Masten was born in Goshen, Mahoning County, Ohio, October 16, 1865. After the usual common school education he was graduated from Northeastern Ohio Normal College, at Canfield, Ohio.

He was first employed in the legal department of the Big Four Railroad where he studied law. He entered the office of Harvey D. Goulder in 1893 and was admitted to the firm of Goulder, Holding and Masten in 1898. In 1910, with other members of this firm, he established the firm of Holding, Masten. Duncan, and Leckie, which connection he held at the time of his death.

He specialized in maritime law and marine insurance and was widely known for his ability as an admiralty lawyer. He was closely identified with the progress of marine matters throughout the United States, and was particularly active in promoting the interests of Great Lakes shipping. He was actively identified with the work of organizing the Lake Carriers' Association when it was incorporated in 1903.

Mr. Masten died January 4, 1918, beloved by all who had ever come in contact with him, either in a business or a social way.

THOMAS S. MATHEWSON

ASSOCIATE

Mr. Mathewson was the eldest son of the late Thomas D. and Mary Stafford Mathewson. He was born in Rhode Island, but spent his early life in San Francisco, California. Later Mr. Mathewson came to New York and became an expert accountant. He is survived by a wife and two daughters.

Mr. Mathewson died September, 1918.

COMMODORE JACOB W. MILLER

VICE-PRESIDENT

The death of Commodore Miller, on March 9, 1918, removes the name of one of our few remaining Charter Members, as well as a familiar and popular personality at all of our meetings. He was born at Morristown, N. J., in 1847 and entered the United States Naval Academy in 1863, graduating, with credit, in 1867. He served in the Navy almost twenty years, resigning in 1884 with the rank of lieutenant.

It is interesting to note, in view of the important work which he carried out during the last years of his life, that during his naval career he took part in the surveys of the Nicaragua route for an inter-oceanic canal. Upon leaving the Navy, he became general manager of the famous Fall River Line of steamers, and later vice-president and general manager of the New England Steamship Company. It was while engaged in this important work that he became one of the Charter Members of our Society; and it may be remarked that it was an essential part of the original plan of the Society to make it an organization for the men who operate vessels as well as for the men who design and build them.

When the scheme for cutting a canal through Cape Cod began to take active shape, the projectors were fortunate in securing the services of Commodore Miller as vice-president and general manager, owing to his work, already mentioned, in connection with the Nicaragua Canal. It is very gratifying to know that he had the pleasure of bringing this enterprise to a successful conclusion, and to enjoy the satisfaction of its operation for several years before his death.

Commodore Miller earned his title by the splendid work to which he devoted his spare time for many years, of organizing and perfecting the New York Naval Militia. His training and experience as a naval officer thoroughly fitted him for this work; and his personal popularity enabled him to secure the cooperation in the early years of a number of younger men who, like himself, were graduates of the Naval Academy. Perhaps if he had been asked to select the work on which he would like his reputation to rest, it would have been the Naval Militia.

Commodore Miller was a member of the Council from the earliest days of the Society and had been a vice-president for nearly ten years. He was devoted to the interests of the Society, a faithful attendant at all its meetings, and a frequent contributor to the Transactions, both by papers and by discussions. He did not show his years, and it probably would be a surprise to

those of the members who were not intimately acquainted with him that he was seventy years old at the time of his death.

The Council and Members of The Society of Naval Architects and Marine Engineers in convention on this date in taking note of the death of Commodore Jacob W. Miller—

"Resolved, That the Society hereby places on record its profound sorrow at the loss of one of its Charter Members who had been a vice-president for many years, and who had greatly contributed to the success of the Society by his activity and constant attention to its interests.

"Resolved, That it has been a privilege to be associated with Commodore Miller in the work of the Society and that we feel a deep sense of personal sympathy in their affliction while we congratulate them on the splendid and useful records made by our friend.

"Resolved, That these resolutions, with the acccompanying notes of the career of Commodore Miller, be inserted in the Transactions of the Society, and that a copy be sent to his family."

STEVENSON TAYLOR,
President.

DANIEL H. COX,
Secretary.

November 14, 1918.

COLONEL EDWIN AUGUSTUS STEVENS

HONORARY VICE-PRESIDENT

The Society has been peculiarly unfortunate during the past year in losing three vice-presidents, who were also among its oldest and most honored members. The Society has, during its entire history, been very fortunate in the devotion of a number of prominent members of the profession who were with it from the beginning; and of these Colonel Stevens stands out as one of the most prominent and useful. He contributed papers frequently, and was always ready to take part in the discussion of those where his experience and ability enabled him to contribute data or to assist in the elucidation of a problem.

Colonel Stevens was born in Philadelphia, March 14, 1858, and died in Washington, D. C., March 9, 1918. His talent as an engineer came to him

by inheritance, as he was a member of the famous Stevens family, of which Col. John Stevens constructed the first successful twin-screw vessel; Robert L. Stevens designed the Stevens battery; and his father, also Edwin A. Stevens, founded Stevens Institute, which has turned out so many notable engineers. Curiously enough, Colonel Stevens did not take a technical course, but graduated at Princeton in 1879. His whole life, however, was given to engineering work, and he did some notable things, of which perhaps the most important was the substitution of the screw-propeller for the paddle-wheel in the ferryboats of New York Harbor. He was a pioneer in this work, and built the first screw ferryboat of the modern type, with a screw at each end. This vessel was the ferryboat Bergen, built in 1889.

Colonel Stevens was interested in engineering matters in many ways, besides being president for a number of years of the Hoboken Ferries. He was for a time a member of the firm of Cox & Stevens, Naval Architects and Engineers. He received the degree of Doctor of Engineering from Stevens Institute.

In his earlier years he devoted considerable time to the militia of New Jersey, and his title of colonel was earned by the command of the Second Regiment of the National Guard of New Jersey. He had also been president of the New Jersey Commissioners of Palisades Park.

For the last few years his duties as Commissioner of Roads and Bridges of the State of New Jersey had prevented his active work with our Society, but until that time he had been one of the most regular and useful attendants at the meetings of the Council and of the Society. He had been a vice-president for a great many years, and was made one of the Honorary Vice-Presidents in 1912. He was a member of the Institution of Naval Architects of Great Britain, and had been Vice-President of the American Society of Mechanical Engineers.

Colonel Stevens was a man of great personal charm, and it is safe to say that all who were honored with his friendship counted it a special privilege. It is interesting to note that the colonel's son, and namesake, read his first paper before the Society at its twenty-first meeting, a fact which was commented upon at the time, as showing that the Society had come of age because the second generation was beginning to take an active part.

The Council and Members of The Society of Naval Architects and Marine Engineers in convention on this date, taking note of the death of Col. Edwin A. Stevens—

"*Resolved,* That the Society wishes to express its great sorrow at the passing of one of its most valued members, who had been a vice-president for many years and was an Honorary Vice-President at the time of his death,

and who had always devoted himself to the advancement of the interests of the Society.

"*Resolved,* That appreciating the privileges of association with Colonel Stevens, his death comes to us all as the loss of a personal friend; and we tender to his family our sincere sympathy in their affliction, while we take pride with them in his fine and useful record.

"*Resolved,* That these resolutions, with the accompanying notes of the career of Colonel Stevens, be inserted in the Transactions of the Society, and that a copy be sent to his family."

STEVENSON TAYLOR,
President.

DANIEL H. COX,
Secretary.

November 14, 1918.

IGNATIUS E. THAYER

MEMBER

Ignatius E. Thayer was born on March 28, 1840. He served his apprenticeship as ship's carpenter in the Charleston Navy Yard, Boston. He and his cousin, Philip Hichborn (afterwards Chief Constructor, U. S. Navy), were given a special course in draughting and vessel design, including calculations pertaining to structure, stability, etc. He completed his apprenticeship in time to answer Lincoln's first call for volunteers. After serving and receiving his discharge he was requested to go to California to the Mare Island Navy Yard, where at that time it was thought probable that a number of government ships would be built. He arrived in the summer of 1862.

In 1878, while on the Island of Tahaiti he bought the burned derelict, Ada Iredale, a British bark, for a small sum. This vessel was burned out completely. With hardly more than a blacksmith's outfit, he rebuilt the vessel, which became the Annie Johnson, and is still in profitable service.

In 1901 Mr. Thayer bought the wrecked bark Pyrenees at the Island of Manga Reva, South Pacific, an English ship that had been burned at sea and beached in the lagoon of Manga Reva. He bought this vessel, fitted out a wrecking expedition, and accomplished a successful salvage. The Manga Reva became a very successful ship, making many Cape Horn voyages under the American flag.

In 1898 Mr. Thayer was appointed by the Government to appraise the Canadian sealing fleet and upon his appraisal the international adjustments were made.

In the same year he designed and superintended the construction of the first wooden vessel built to carry oil in bulk. This was the barge Santa Paula, the first piece of shipping property owned by the Union Oil Co. In its day this undertaking was considered rather daring, but was completely successful in spite of the usual prophecies to the contrary.

Mr. Thayer became Pacific coast inspector for the Bureau Veritas in 1880 and held that position for thirty-two years. He resigned in 1913. He was a member of the Technical Committee of the Bureau Veritas and was retained as a member of it until his death. He had, also, been a surveyor for the Norwegian Veritas (Det Norske Veritas) for several years.

Mr. Thayer died May 14, 1918, in his seventy-eighth year.

JOHN D. VAN BUREN

MEMBER

Mr. Van Buren was born in New York City, August 18, 1838. He was a student in the Lawrence Scientific School at Harvard and graduated C. E. from Rensselaer Polytechnic Institute in 1860. He was assistant engineer on the Croton Aqueduct under Alfred Craven, 1860–61. He entered the Engineers' Corps, U. S. N. (Regular), and served in the Gulf of Mexico and also in the Bureau of Steam Engineering, Navy Department, Washington, D. C.

Mr. Van Buren took part in the Peninsular and James River Campaigns, 1862, and was on duty at the Naval Academy at Annapolis as assistant professor for four years. Was commissioned first-assistant engineer (lieutenant) on January 1, 1865. He resigned from the Navy in 1868 and was for several years under Gen. George B. McClellan, Department of Docks, New York City. He was one of the commissioners appointed by Governor Tilden to investigate the canals in 1865, and was State Engineer and Surveyor of New York, 1866–77.

Mr. Van Buren was the author of numerous technical papers and a member of the New York Bar, American Society of Civil Engineers, American Society of Naval Engineers, and a member of this Society since its organization in 1893.

Mr. Van Buren died on March 10, 1918.

WILLIAM H. VARNEY

MEMBER

William H. Varney was born in Wolfboro, New Hampshire, April 19, 1838. He was educated in the Boston High School, taking the Franklin Medal. He then went as apprentice in naval architecture to Samuel K. Pook in Medford and Boston.

Mr. Pook went out of business before Mr. Varney reached his majority, which forced him to go into business for himself before he was twenty-one years of age. He established himself in a mould loft in East Boston, where during the next succeeding eight years he designed over five hundred vessels for the merchants and shipbuilders of Boston and vicinity, many of his vessels being prize winners on long ocean races.

He designed the brig Novelty, which was the first tank vessel to carry fluid in bulk (molasses).

He entered the U. S. Navy in 1869 as assistant naval constructor, his first assignment being Portsmouth, N. H. He was appointed to the rank of naval constructor in 1875. He continued in active service until the date of his retirement, April 19, 1900, when he was retired with the rank of captain, having reached the retiring age.

He superintended the construction of many of the vessels which formed the nucleus of the new Navy in its transition from wood to steel.

He became a member of the Society on its organization in 1893, and remained a member up until the time of his death, May 22, 1918. He leaves a widow and one son, William W. Varney, who is also a member of the Society.

JOHN FRANK WENTWORTH

MEMBER

John F. Wentworth was born at Rochester, N. H., February 1, 1879, and received his preliminary education in the public schools of that town. He received his technical education in the Massachusetts Institute of Technology, being a graduate of the 1900 class of Naval Architecture and Marine Engineering.

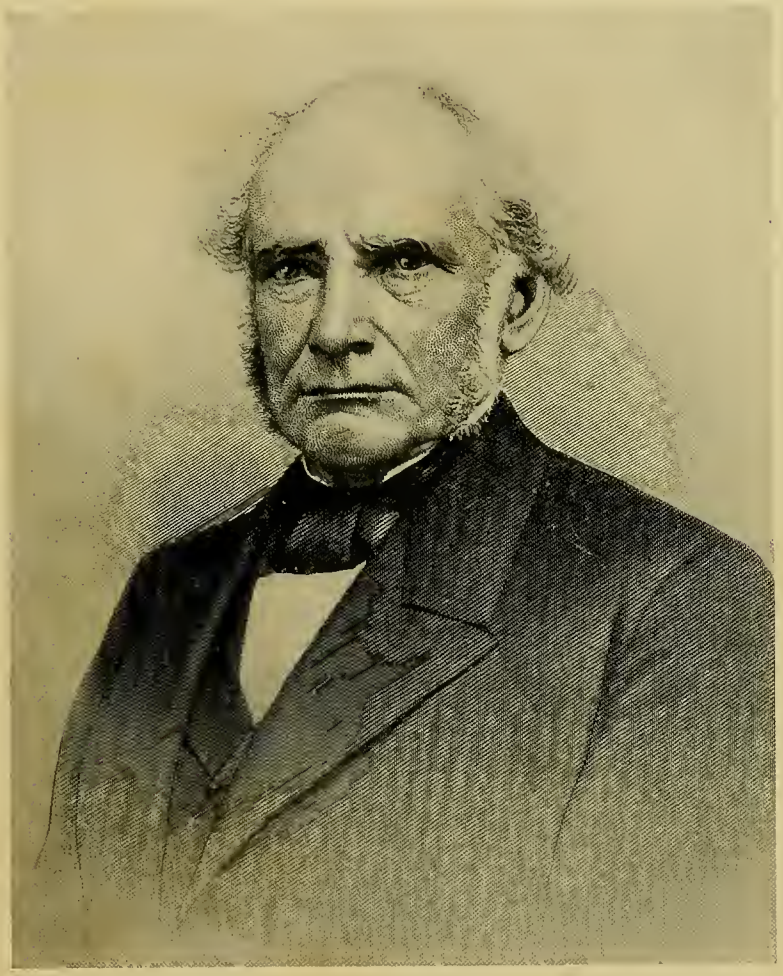
On graduation he obtained employment as a shipfitter's helper at George Lawley & Son, 1900-01, and during part of 1901 he was employed as a draughtsman in the Hull Department of the Fore River Shipbuilding Company, working on structural work and hull fittings. During 1901-05 he was employed as a computer in the scientific branch of the Bureau of Construction and Repair, Navy Department. From 1905 to 1907 he was employed in the office of the superintending constructor, Quincy, Mass., on finished plan work, and from 1907 to the date of his death he was employed in the Boston Navy Yard on finished plans, general alterations, shop management, investigation of heat treatment, and other investigative and laboratory work, including manufacturing and calibration of pyrometers.

Mr. Wentworth was a pioneer in the heavy oil engine field and had numerous patents issued a few years before his death. He read two papers on the subject before this Society.

Mr. Wentworth died on December 20, 1918.

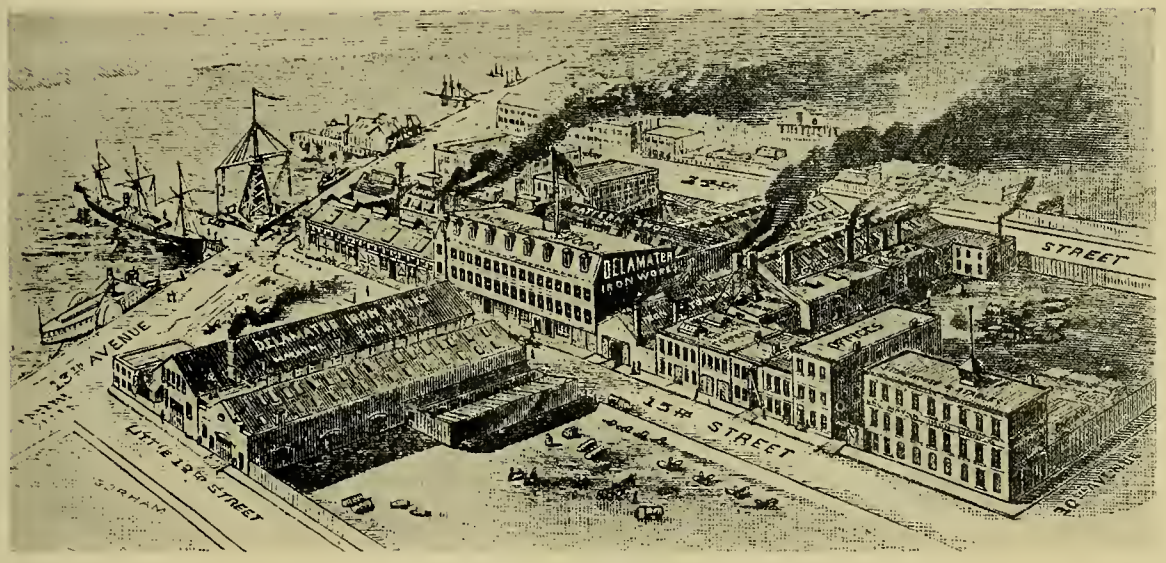
PLATES

To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.



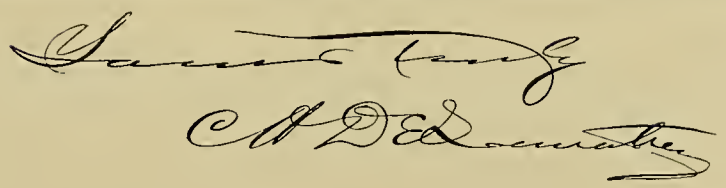
James Cunningham

To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.

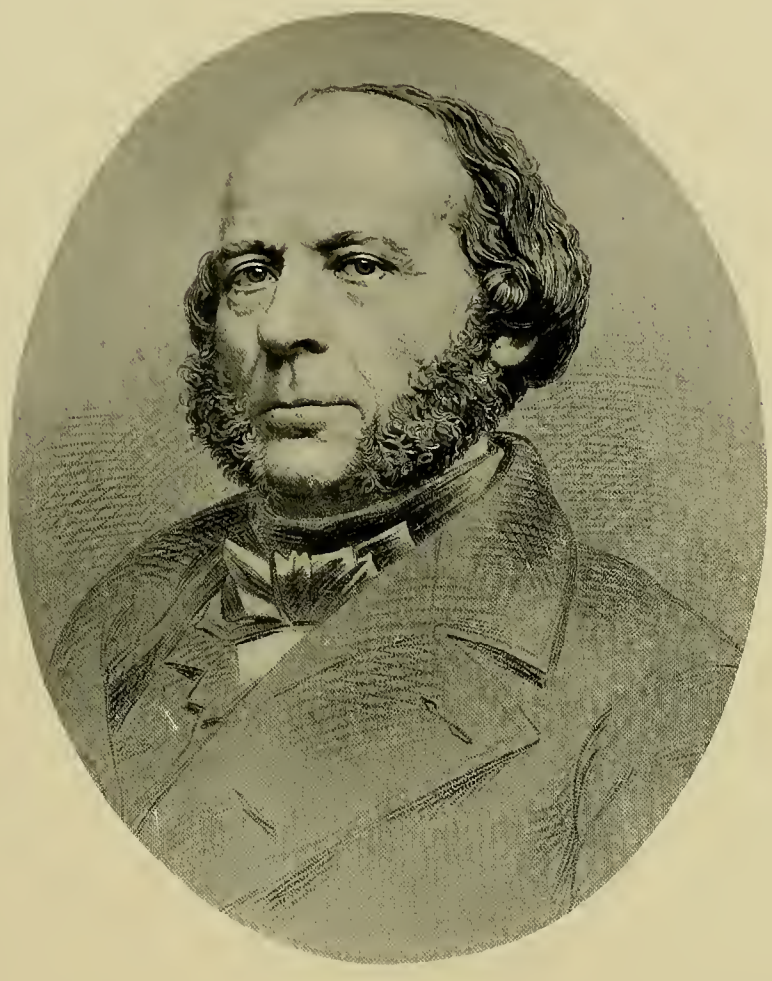


De Lamater Iron Works.

To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.



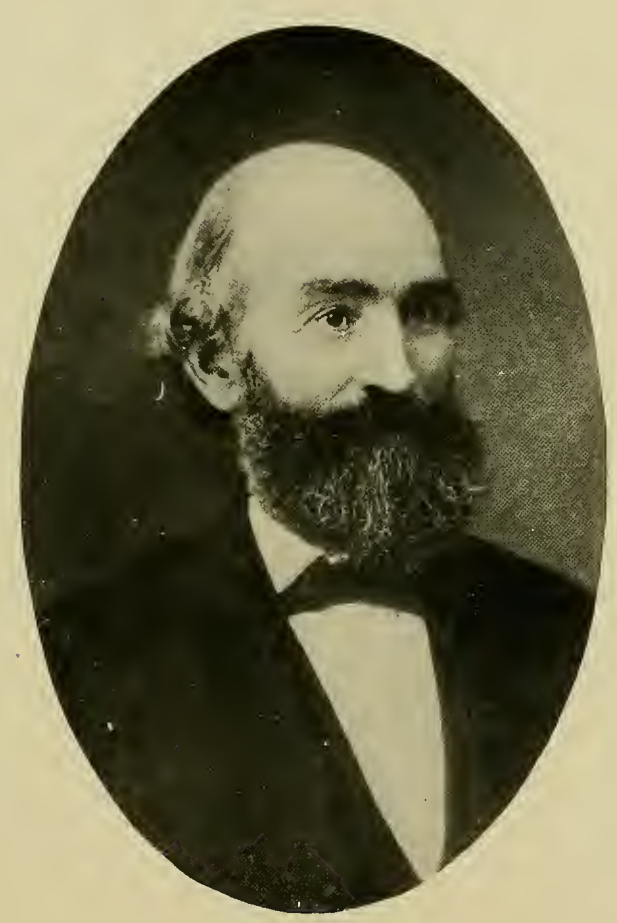
To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.



S. Ericsson

1865

To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.



ALEXANDER K. RIDER.

To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.

CHARLES VAN WAGENEN.

To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.

Geo H Reynolds

To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.

JAMES MILLER.

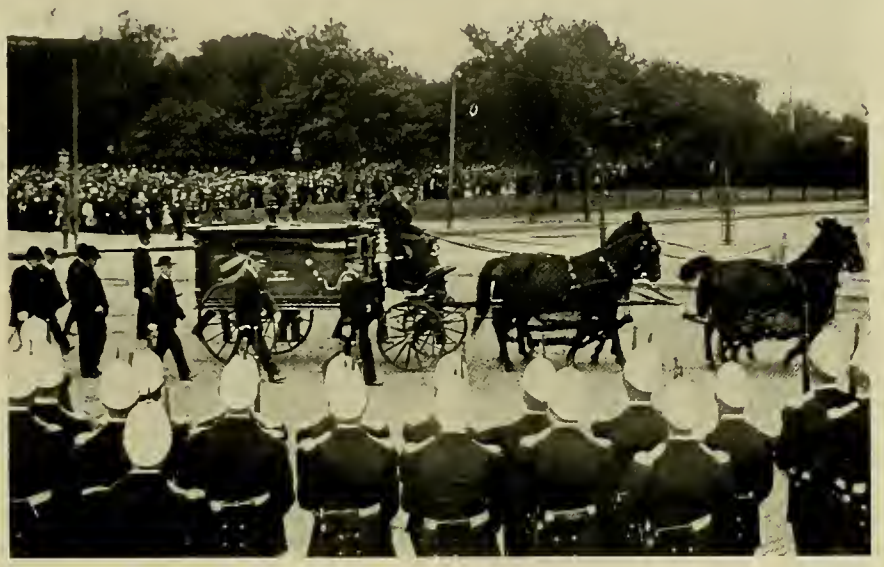
To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.

HUGO B. ROELKER

To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.

THOMAS J. RIDER.

To illustrate paper on "The De Lamater Iron Works—The Cradle of the Modern Navy," by Holbrook Fitz John Porter, M. E., Visitor.



FUNERAL HEARSE.

FUNERAL TUG.

To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos deZafra, Esq., Associate.

Site of a Wooden Shipyard at Tacoma, Wash., August, 1917.

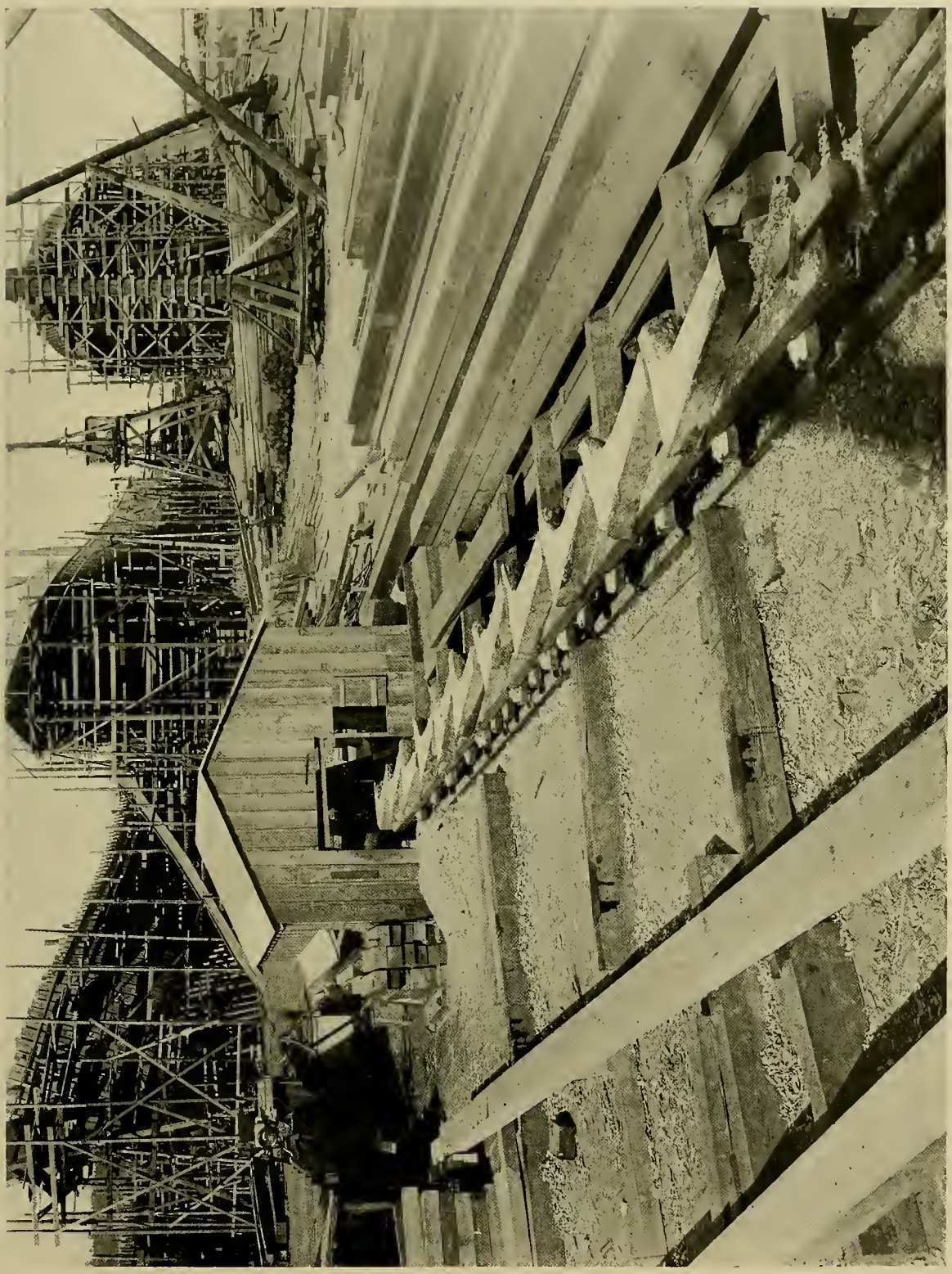
To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos deZafra, Esq., Associate.

Site of Wooden Shipyard, Tacoma, Wash., October 15, 1917.

To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry,"
by Carlos deZafra, Esq., Associate.

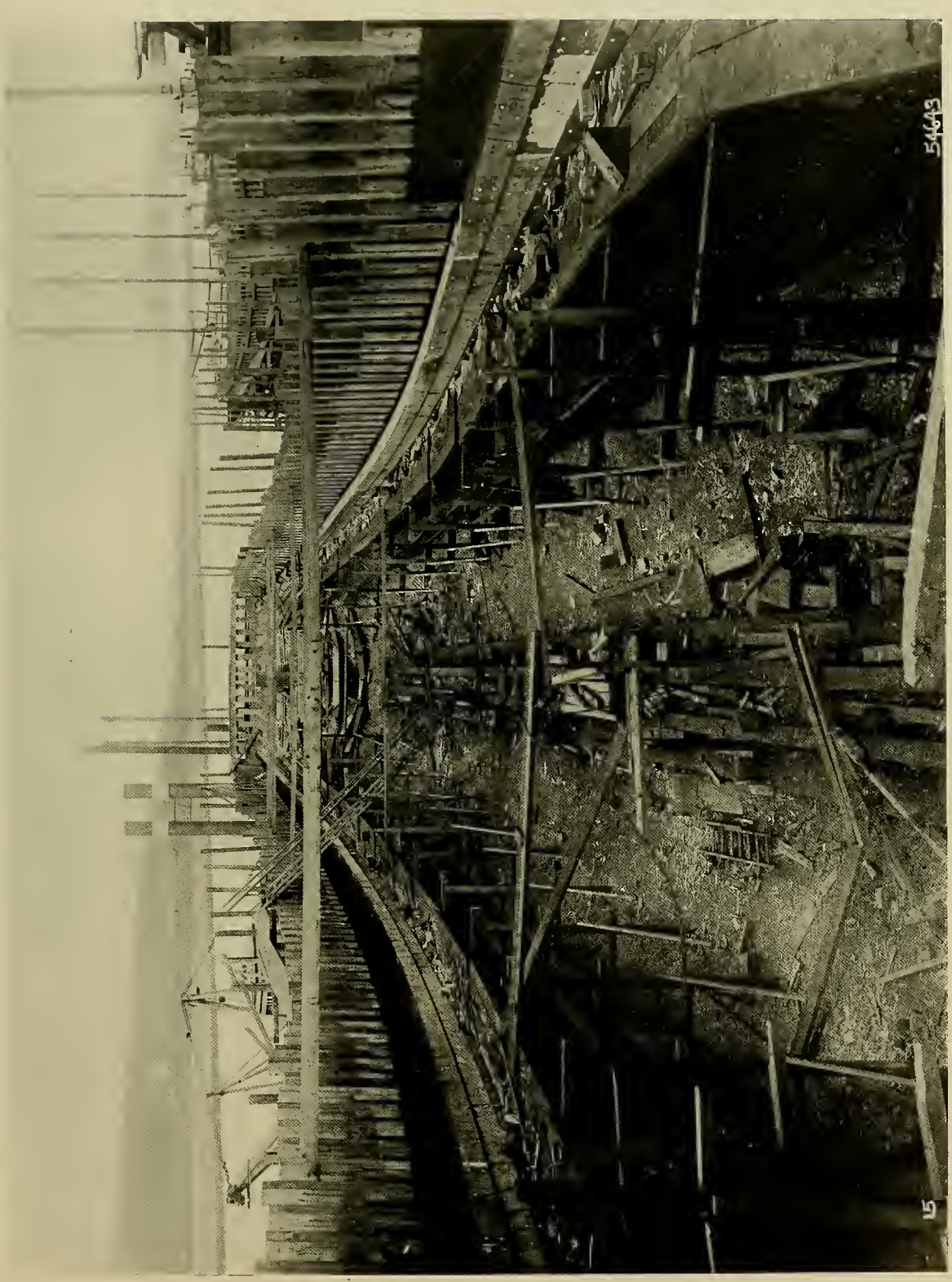
[illegible] Wash. October 27, 1917

To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos deZafra, Esq., Associate.



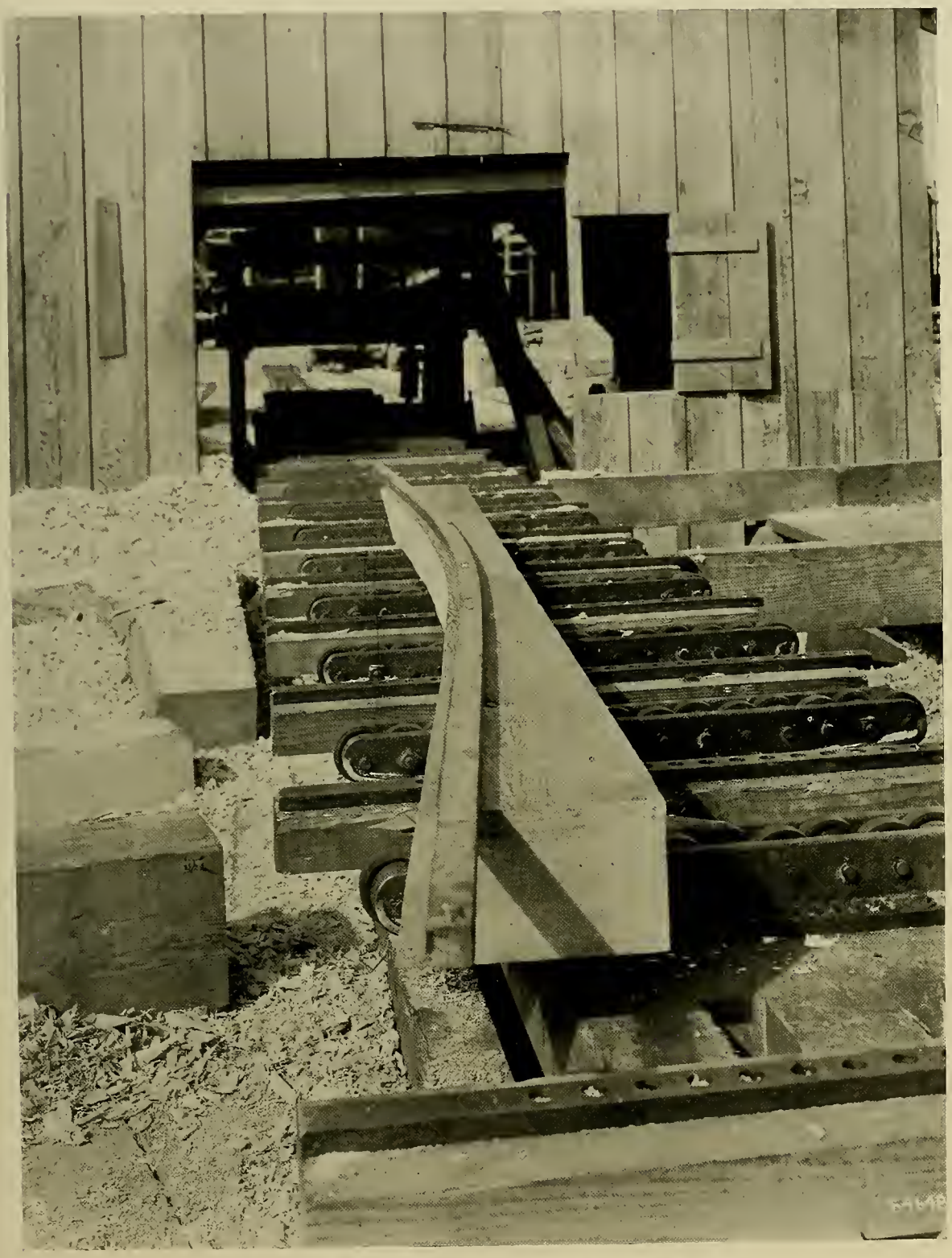
MACHINE SURFACING OF SHIP'S KNEES.

To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos de Zafra, Esq., Associate.



INSTALLATION OF MACHINE-BEVELLED CEILING.

To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos deZafra, Esq., Associate.



SPECIMEN OF COMBINED REVERSE AND CURVED BEVELLING BY MACHINE.

To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos deZafra, Esq., Associate.

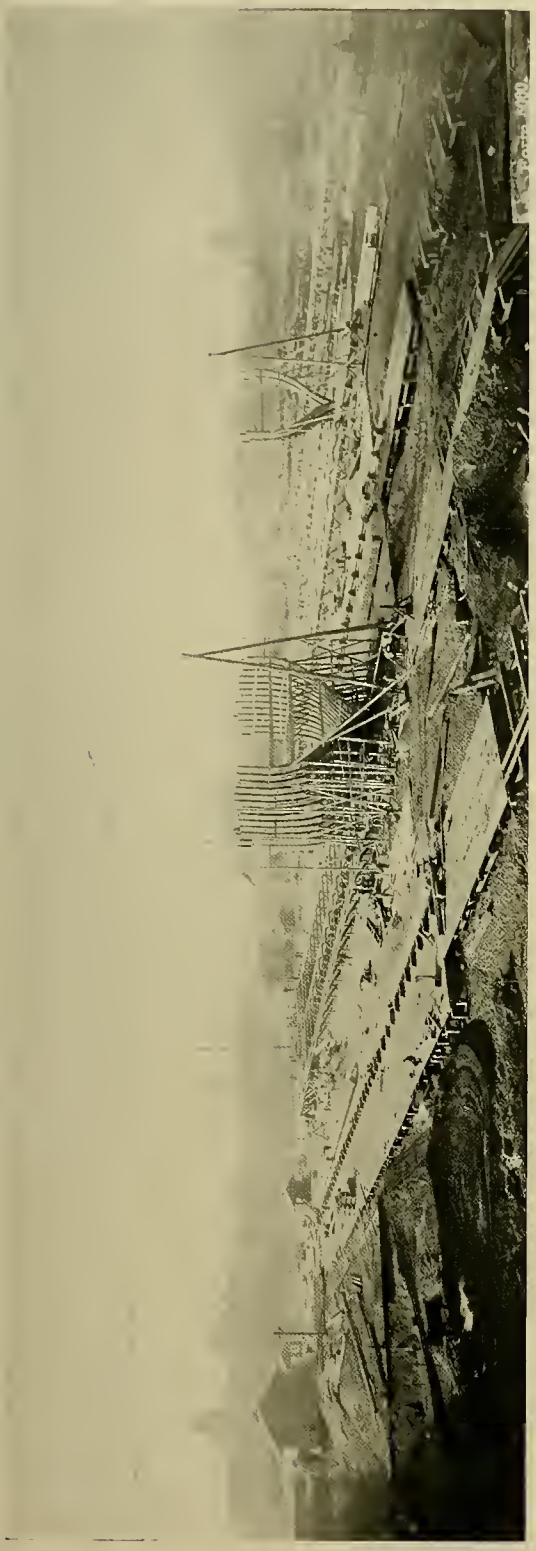


Fig. 1.—Frame Erection, November 2, 1917.

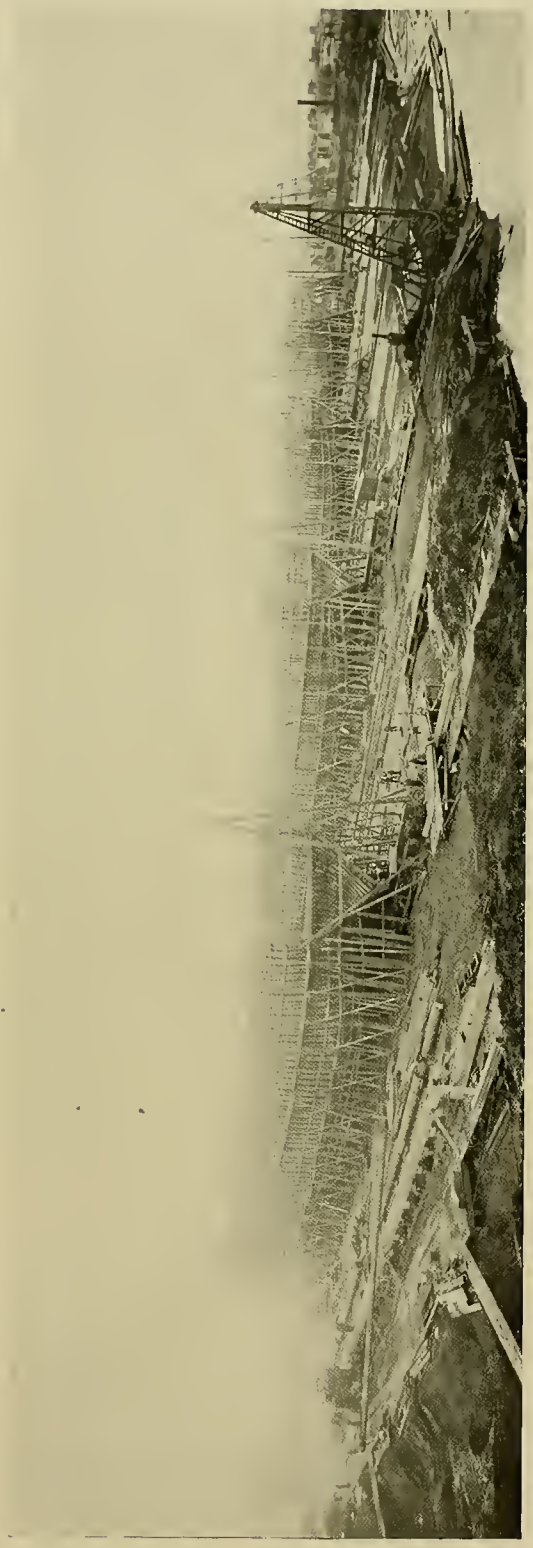
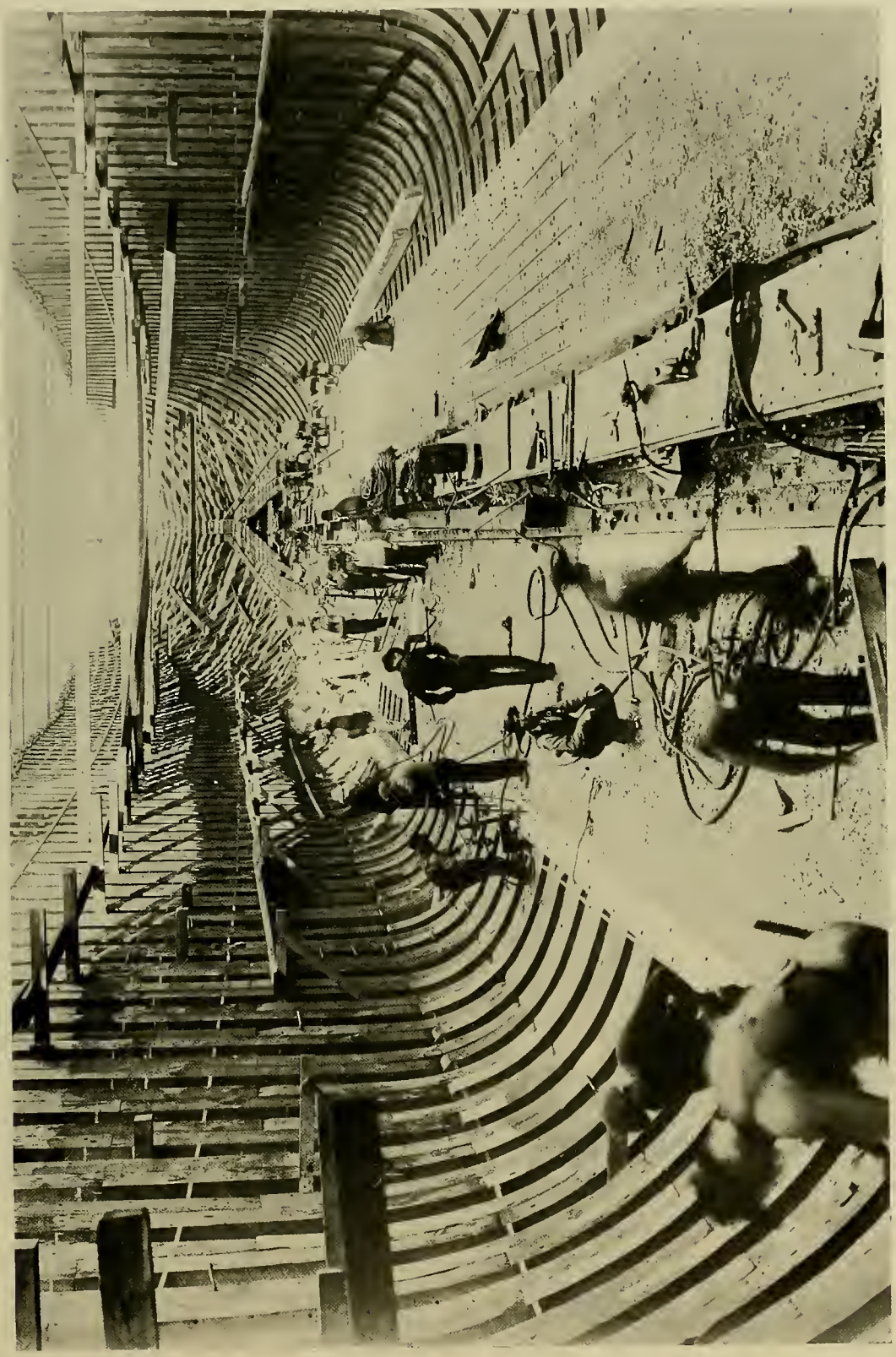


Fig. 2.—Same as Above, November 14, 1917 (12 Days Later).

To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos deZafra, Esq., Associate.

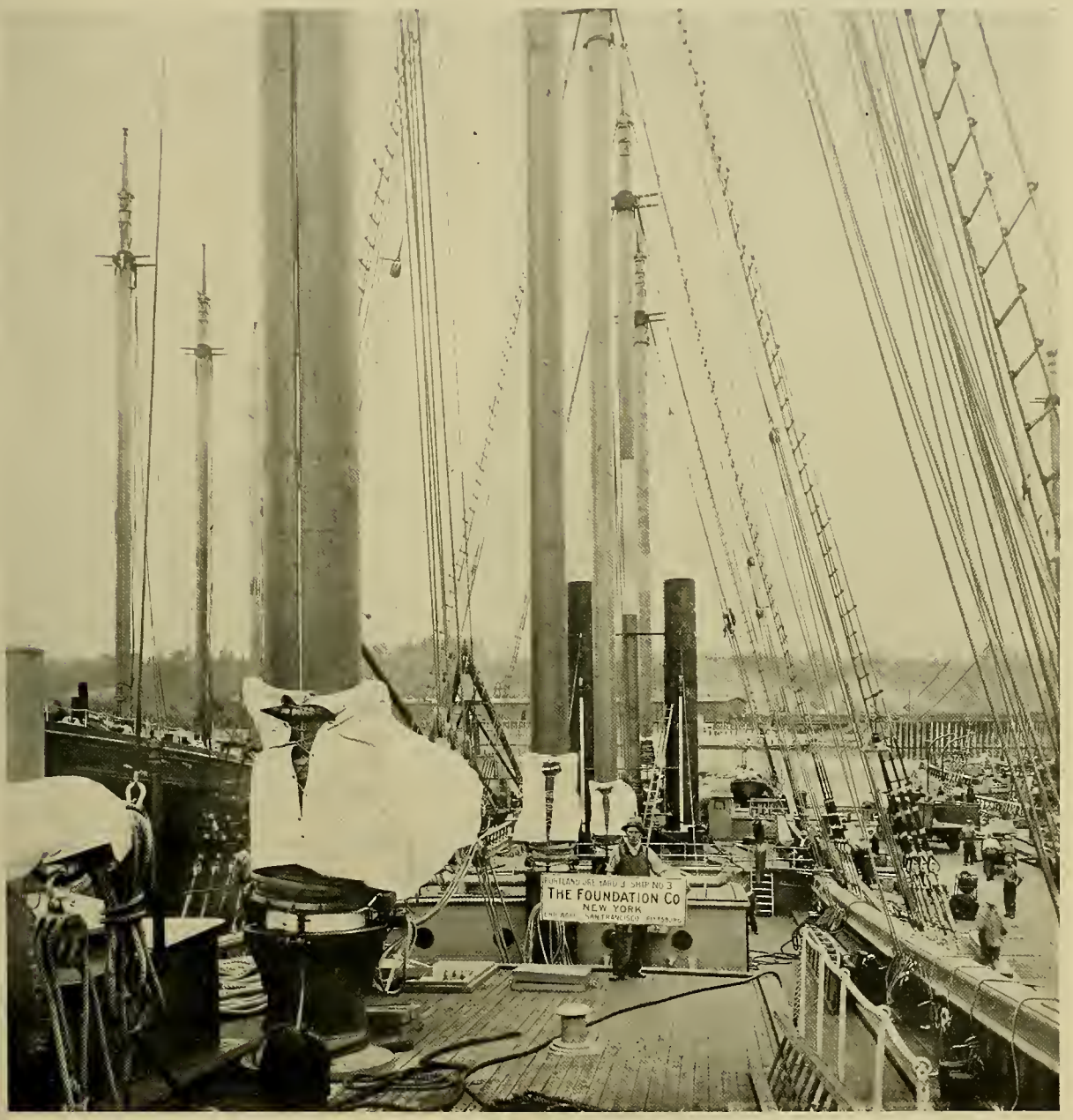


Assembling Steel Keelson in 2,500 T. D. W. Wooden Steamer.

To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos deZafra, Esq., Associate.

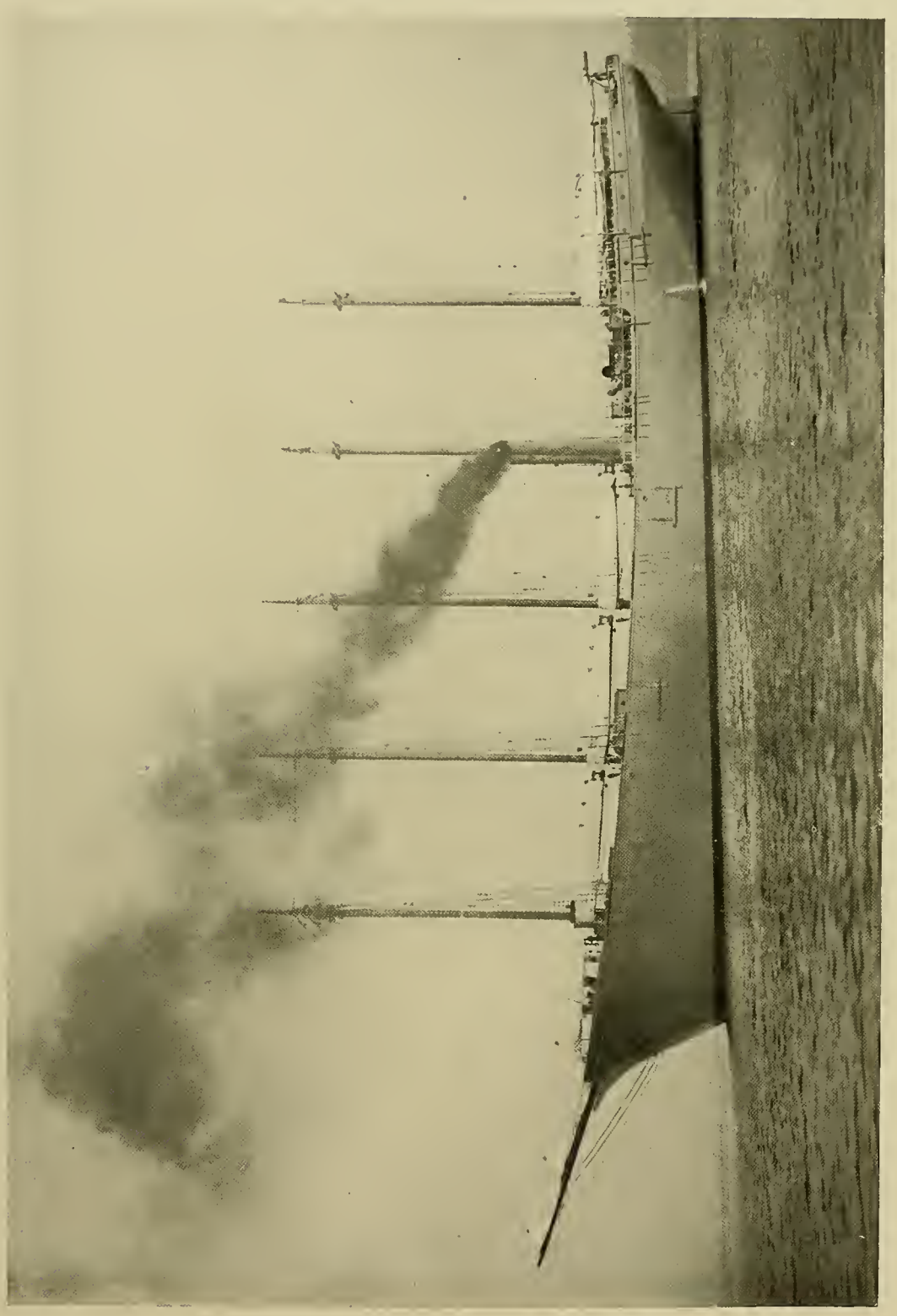
Sliding New Keel on Ways During Launching Ceremonies.

To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos deZafra, Esq., Associate.



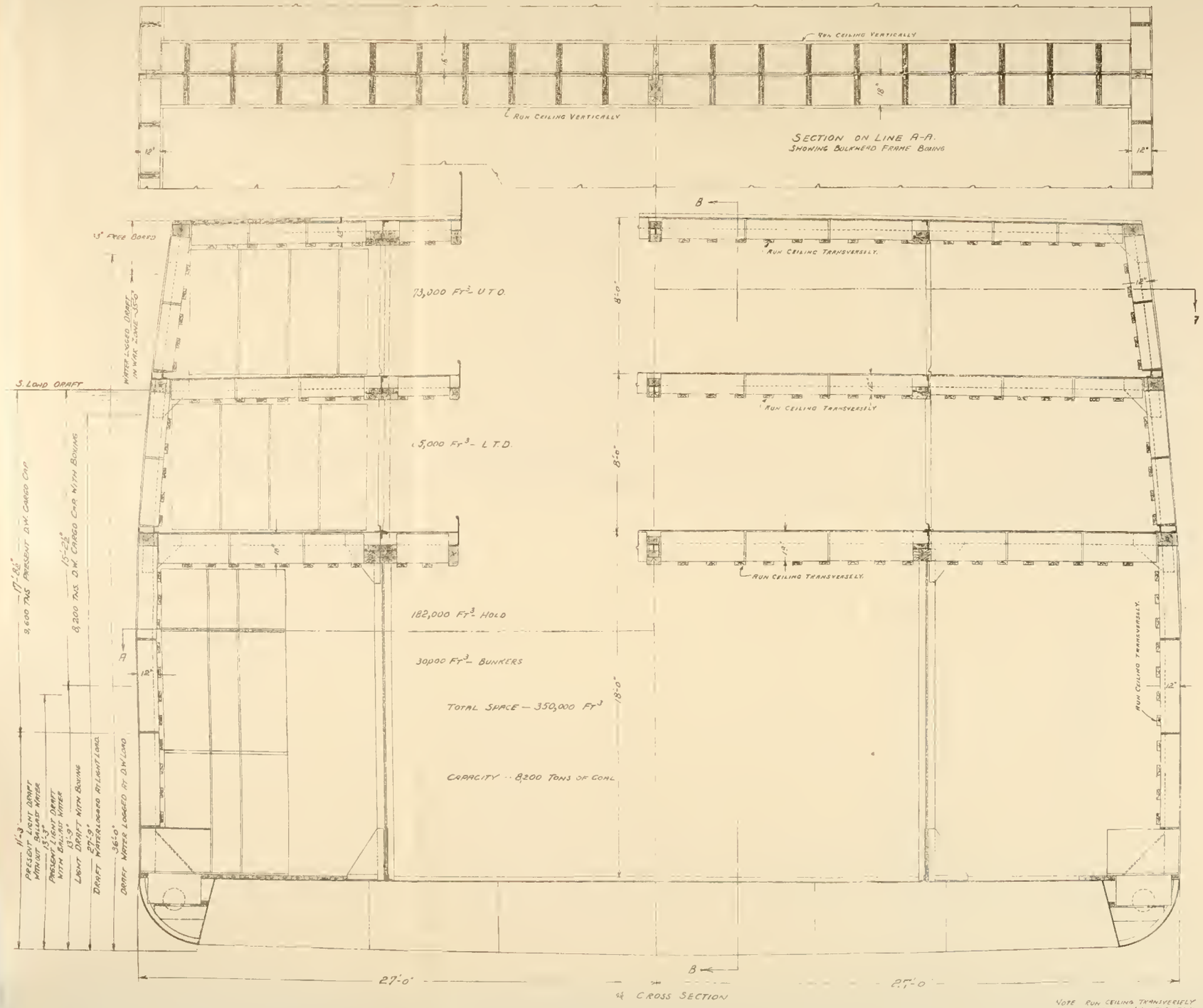
Rigging View of 3,000 T. D. W. Auxiliary Schooner.

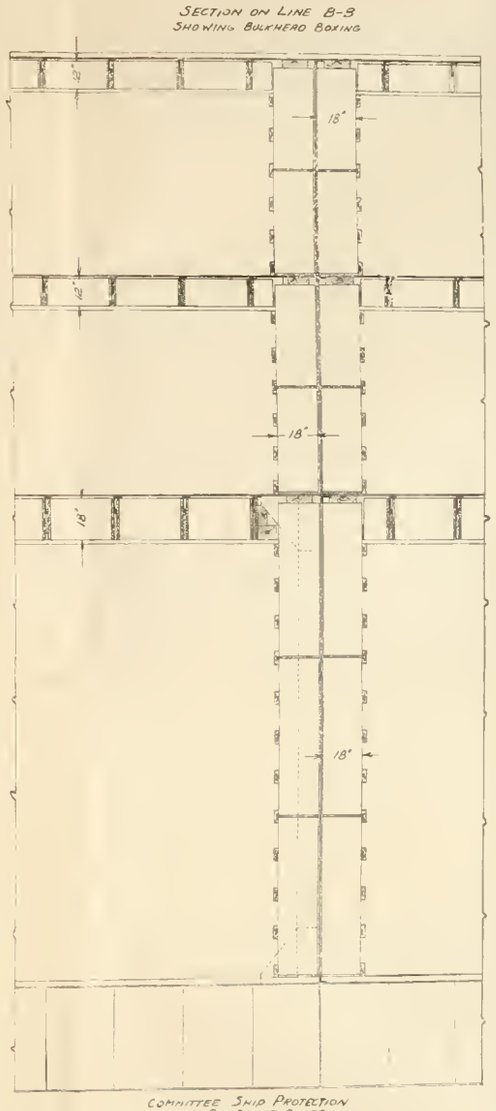
To illustrate paper on "Revival of Wooden Shipbuilding as a War Industry," by Carlos deZafra, Esq., Associate.



TYPE OF 3,000 T. D. W. WOODEN TWIN-SCREW AUXILIARY SCHOONER.

To illustrate paper on "Application of Buoyancy Boxes to the Steamship Lucia for the United States Shipping Board," by William T. Donnelly, Esq., Member.





COMMITTEE SHIP PROTECTION
U.S. SHIPPING BOARD
EMERGENCY FLEET CORPORATION
WASHINGTON, D.C.

W. T. DONNELLY METHOD OF INCREASING BUOYANCY OF SHIPS AS APPLIED TO S.S. LUCIA.

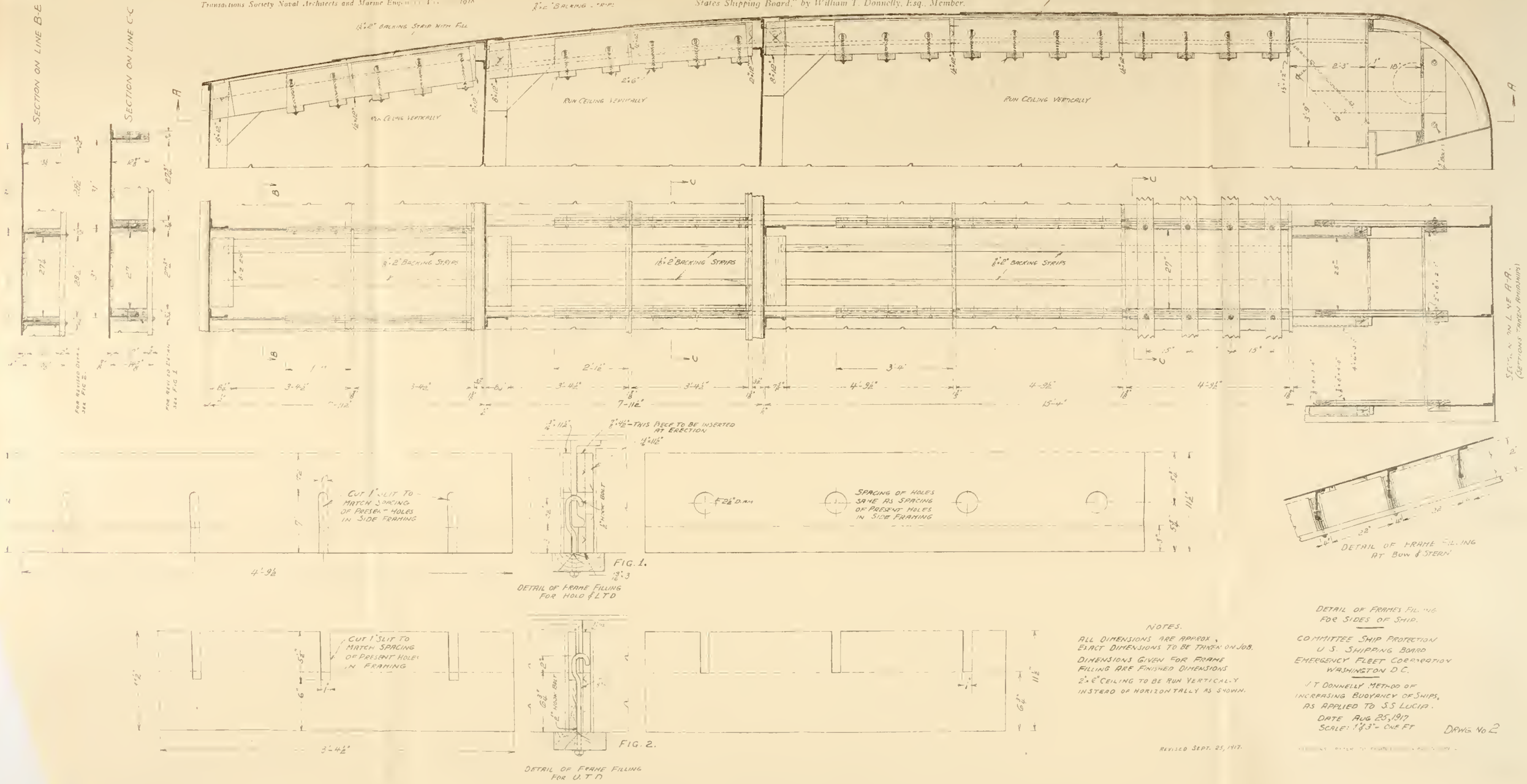
AUG 15, 1917

REVISED SEPT. 25, 1917

DRWG No. 1.

THE BURRIS PRINTING CO. BALTO. U.S.C.

To illustrate paper on "Application of Buoyancy Boxes to the Steamship Lucia for the United States Shipping Board," by William T. Donnelly, Esq., Member.



NOTES.

ALL DIMENSIONS ARE APPROX.
EXACT DIMENSIONS TO BE TAKEN ON JOB.
DIMENSIONS GIVEN FOR FRAME FILLING ARE FINISHED DIMENSIONS
2"x6" CEILING TO BE RUN VERTICALLY INSTEAD OF HORIZONTALLY AS SHOWN.

REVISED SEPT. 25, 1917.

DETAIL OF FRAMES FILLING FOR SIDES OF SHIP.

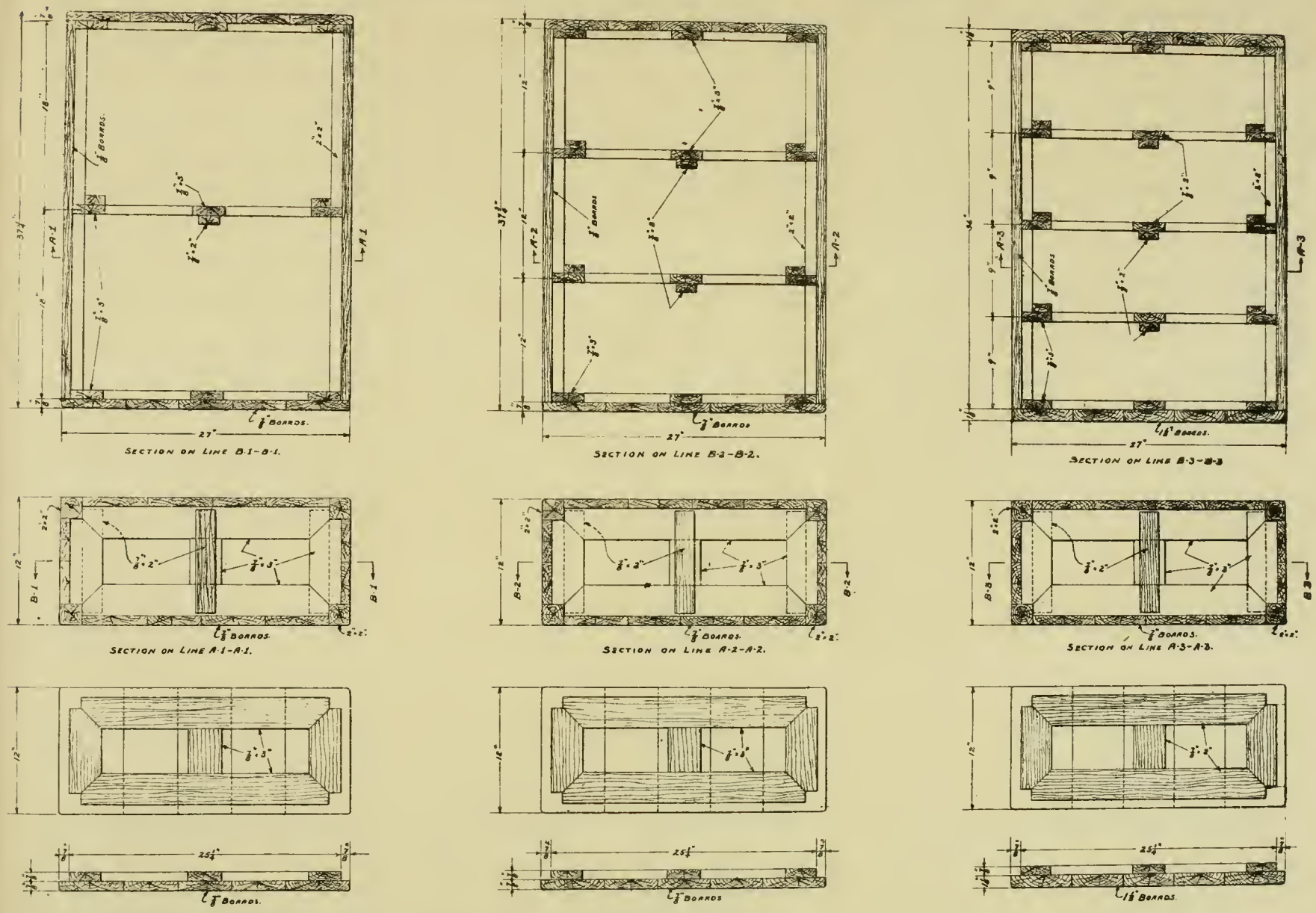
COMMITTEE SHIP PROTECTION
U. S. SHIPPING BOARD
EMERGENCY FLEET CORPORATION
WASHINGTON D.C.

W. T. DONNELLY METHOD OF INCREASING BUOYANCY OF SHIPS, AS APPLIED TO S.S. LUCIA.

DATE AUG. 25, 1917
SCALE: 1½"=1'-0" ONE FT

DRWG. No. 2

To illustrate paper on "Application of Buoyancy Boxes to the Steamship Lucia for the United States Shipping Board," by William T. Donnelly, Esq., Member.



DETAILS OF FLOTATION BOXES.

COMMITTEE SHIP PROTECTION,
U.S. SHIPPING BOARD,
EMERGENCY FLEET CORPORATION.
WASHINGTON, D.C.

W. T. DONNELLY METHOD OF INCREASING BUOYANCY OF SHIPS, AS APPLIED TO S.S. LUCIA.
DATE: AUGUST 9, 1917
SCALE: 3" = ONE FT.

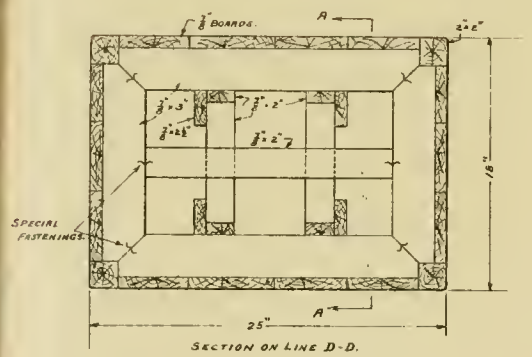
DRWG Nº 6.

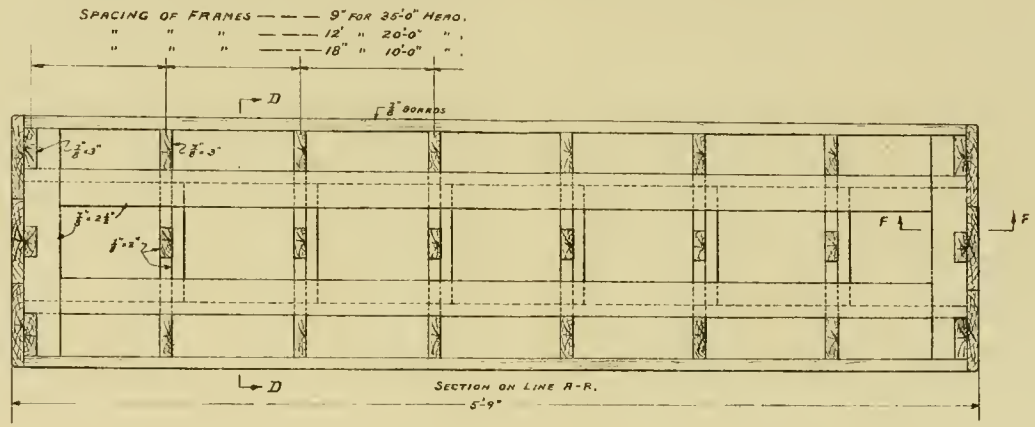
ALL BOXES TO BE MADE FROM #1 NORTH CAROLINA PINE.

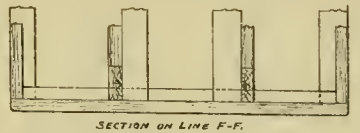
NOTE:
THIS DRAWING TO BE USED FOR DESIGN ONLY.
EXACT DIMENSIONS TO BE TAKEN ON JOB.

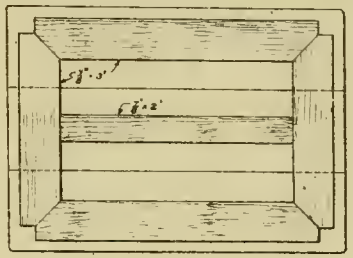
THE HORRIS PRTGRS CO WASHINGTON, D.C.

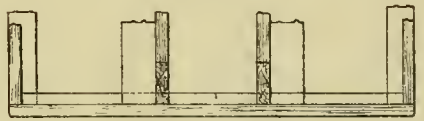
To illustrate paper on "Application of Buoyancy Boxes to the Steamship Lucia for the United States Shipping Board," by William T. Donnelly, Esq., Member.

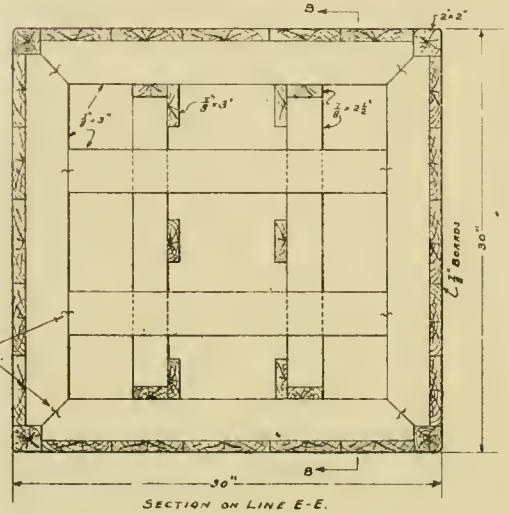


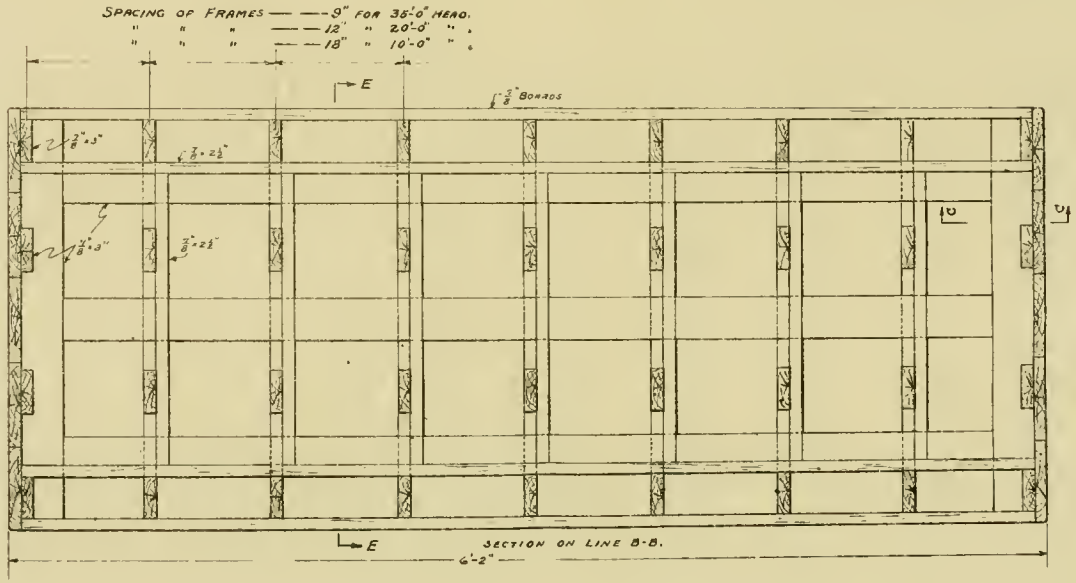


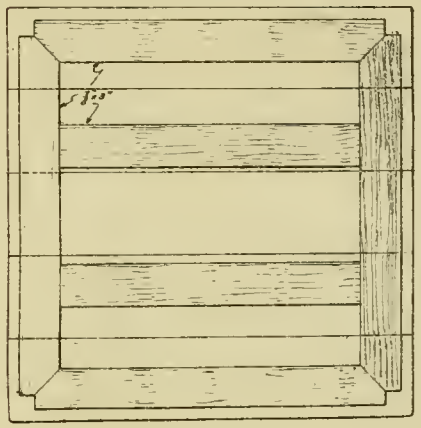












NOTE:
THIS DRAWING TO BE USED FOR DESIGN ONLY.
EXACT DIMENSIONS TO BE TAKEN ON JOB.

DETAILS OF FLOTATION BOXES.

COMMITTEE SHIP PROTECTION
U.S. SHIPPING BOARD
EMERGENCY FLEET CORPORATION
WASHINGTON, D.C.

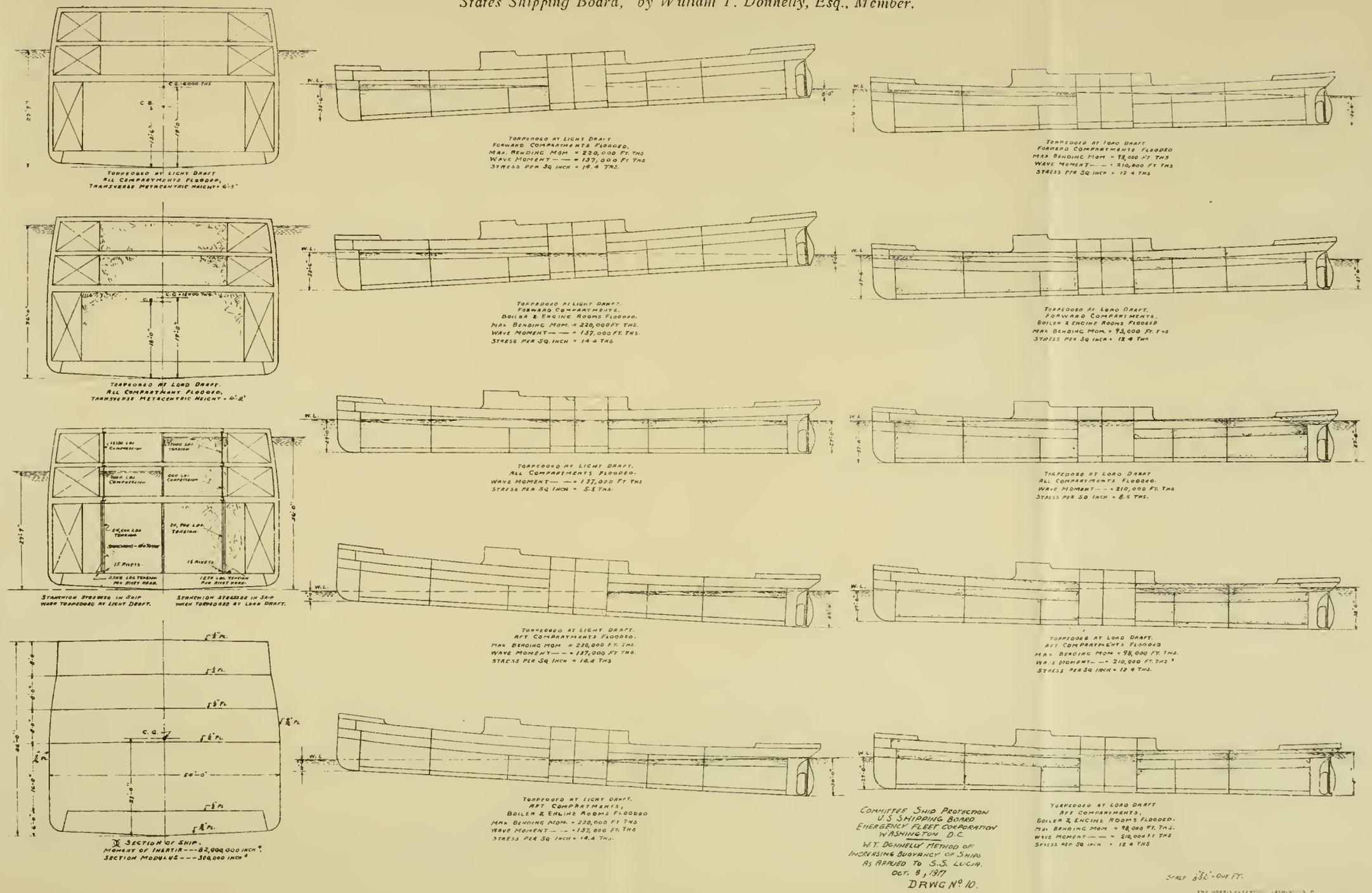
W. T. DONNELLY METHOD OF INCREASING BUOYANCY OF SHIPS, AS APPLIED TO S.S. LUCIA

DATE: SEPT. 11, 1917.
SCALE: 3" - ONE FT.

DRWG Nº 7.

THE NORRIS PETERS CO. WASHINGTON, D.C.

To illustrate paper on "Application of Buoyancy Boxes to the Steamship Lucia for the United States Shipping Board," by William T. Donnelly, Esq., Member.



To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

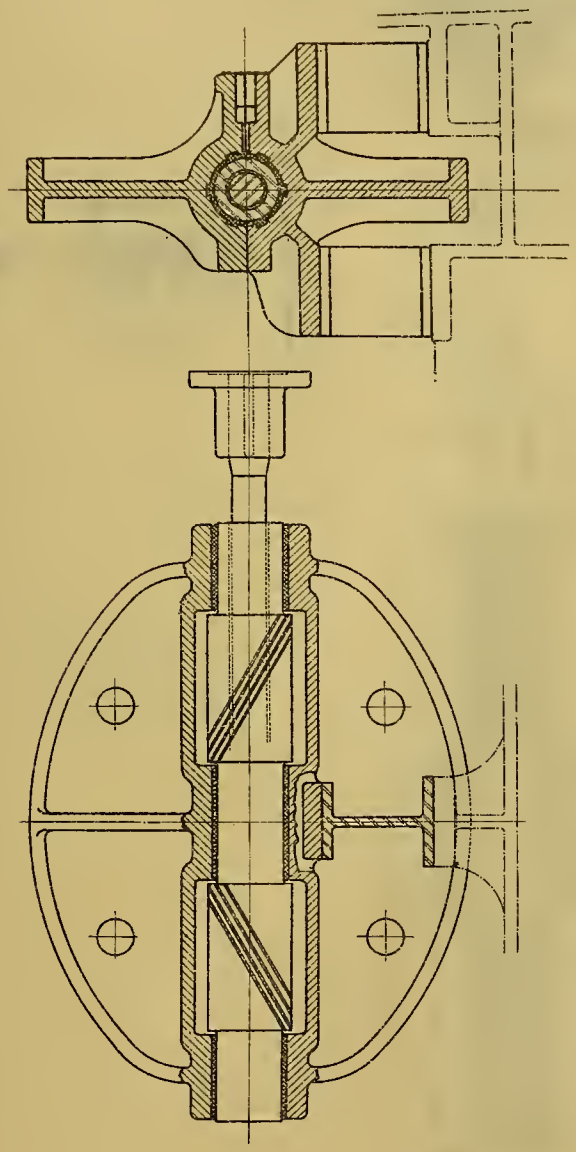


ILLUSTRATION OF FLEXIBLE PINION FRAME WITH I SUPPORTS

Fig. 1 - I-Beam Support.

THE NORRIS-PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

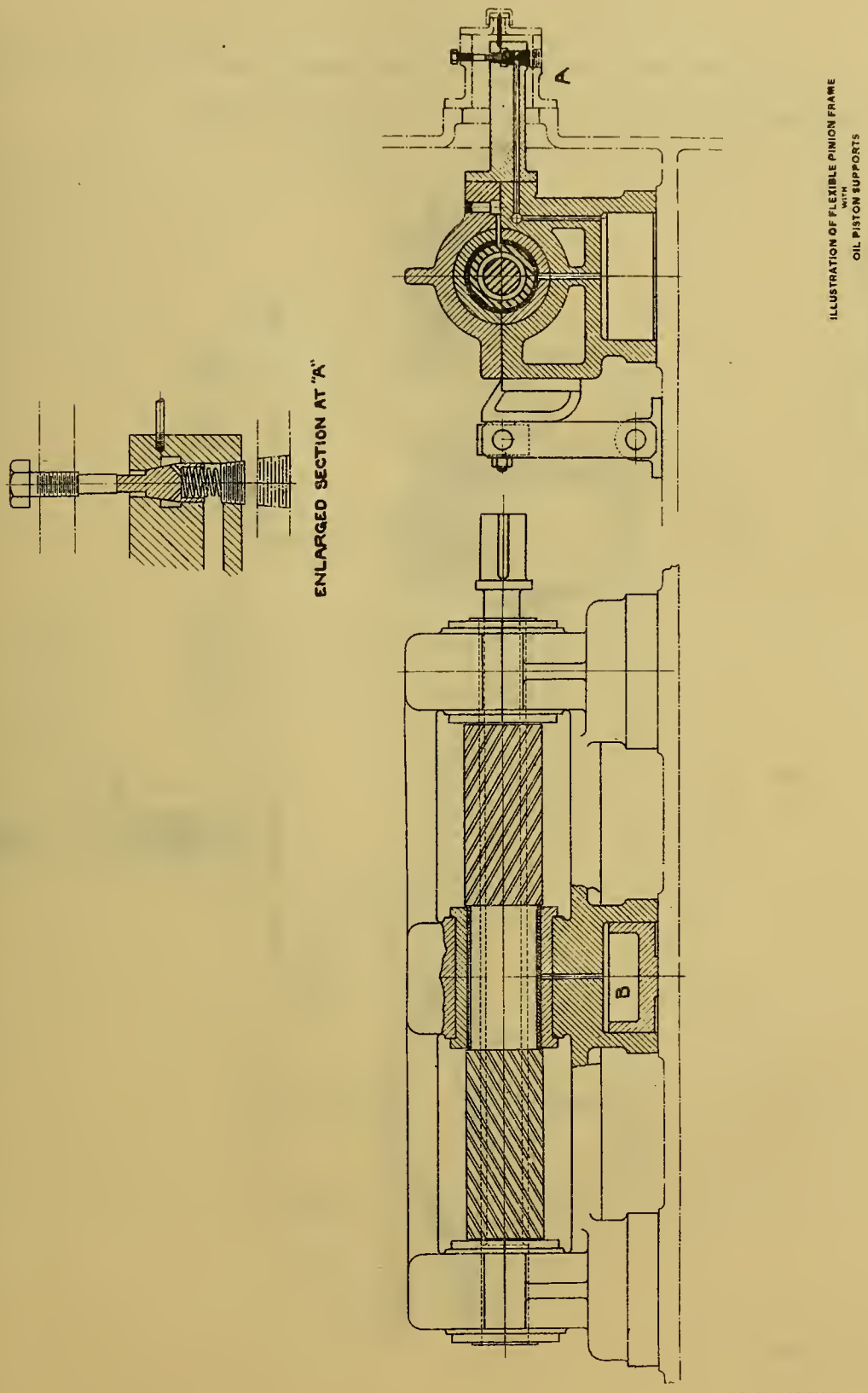


Fig. 2 - The Piston Floating Frame.

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To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

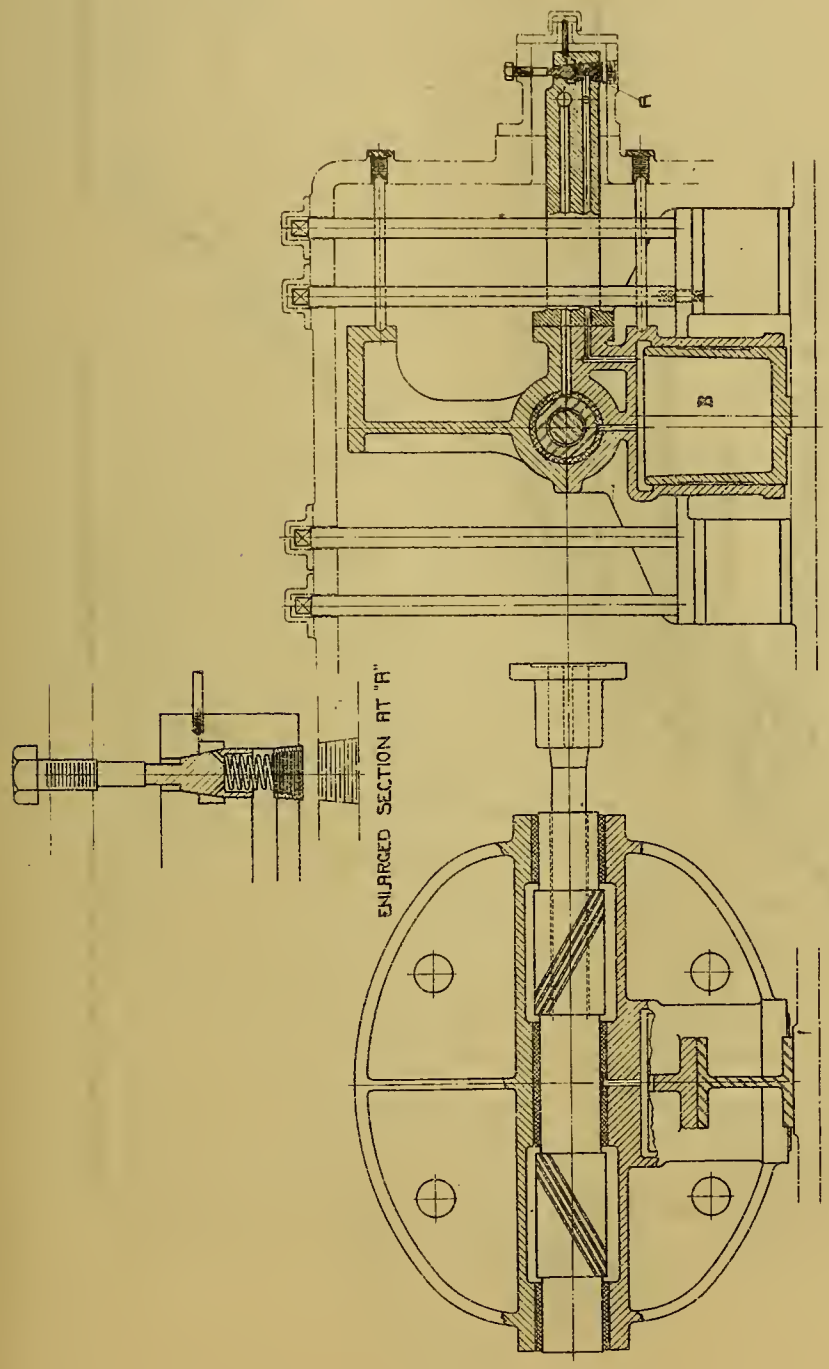

ILLUSTRATION OF FLEXIBLE PINION FRAME WITH OIL PISTON & I SUPPORTS

Fig. 3 - Combination of Dynamometer and I-Beam Support.

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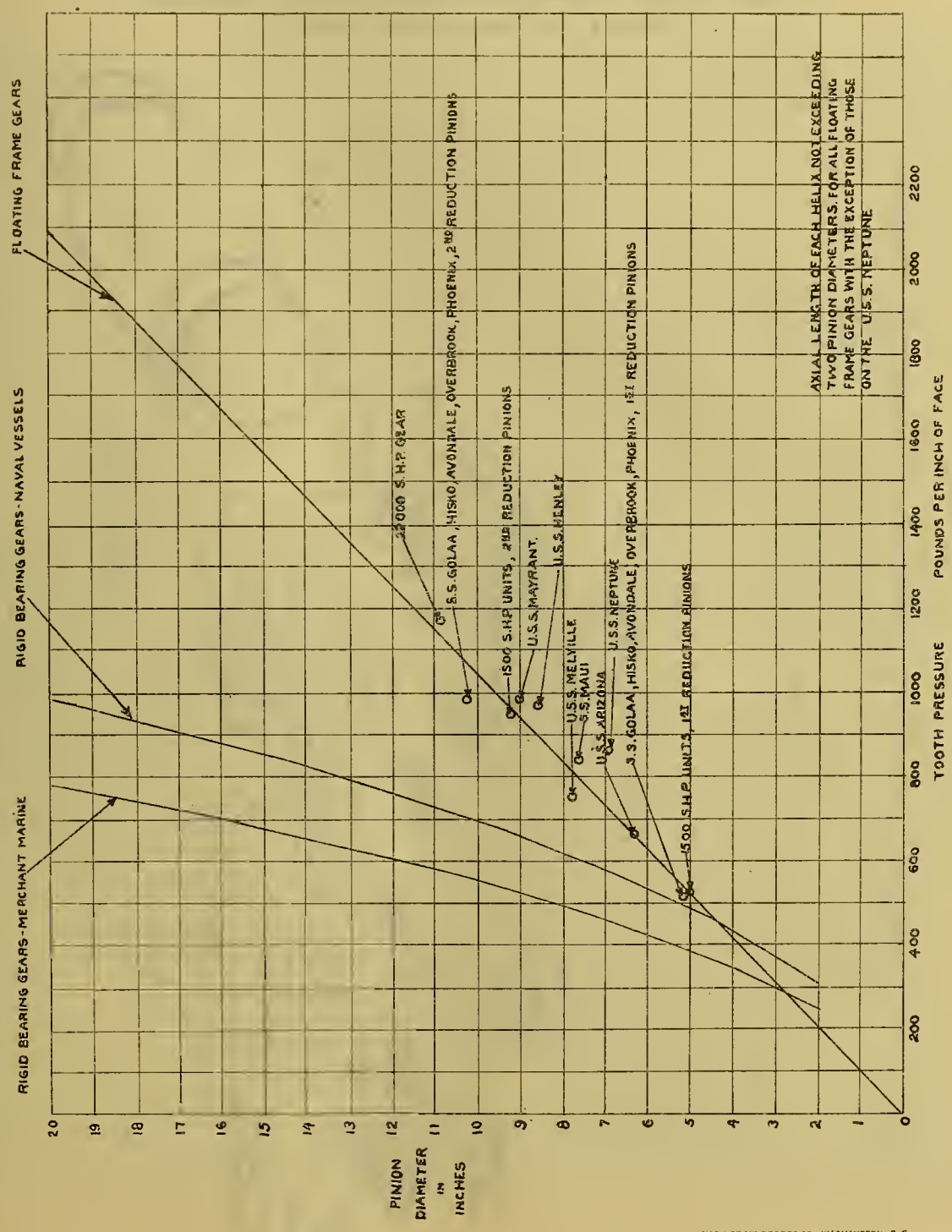

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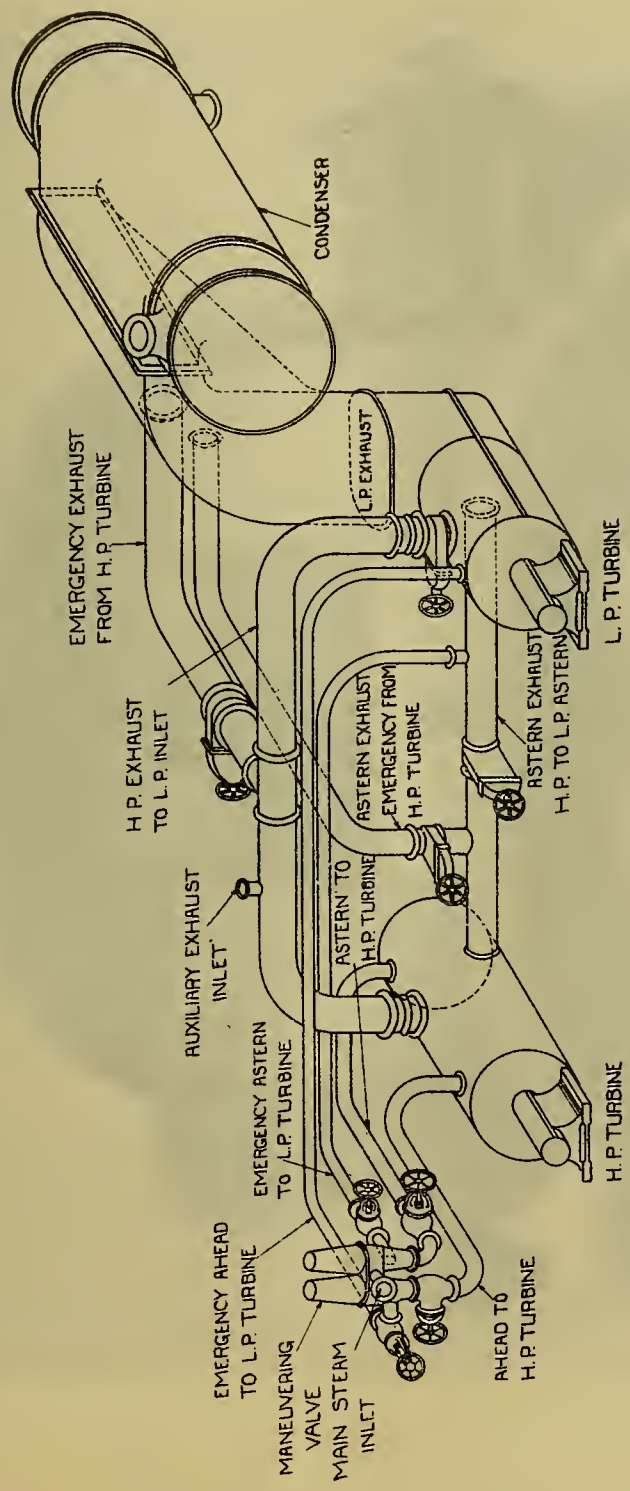
To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.



STEAM PIPING DIAGRAM

Fig. 5 - Arrangement of Valves for Cross Compound Installation.

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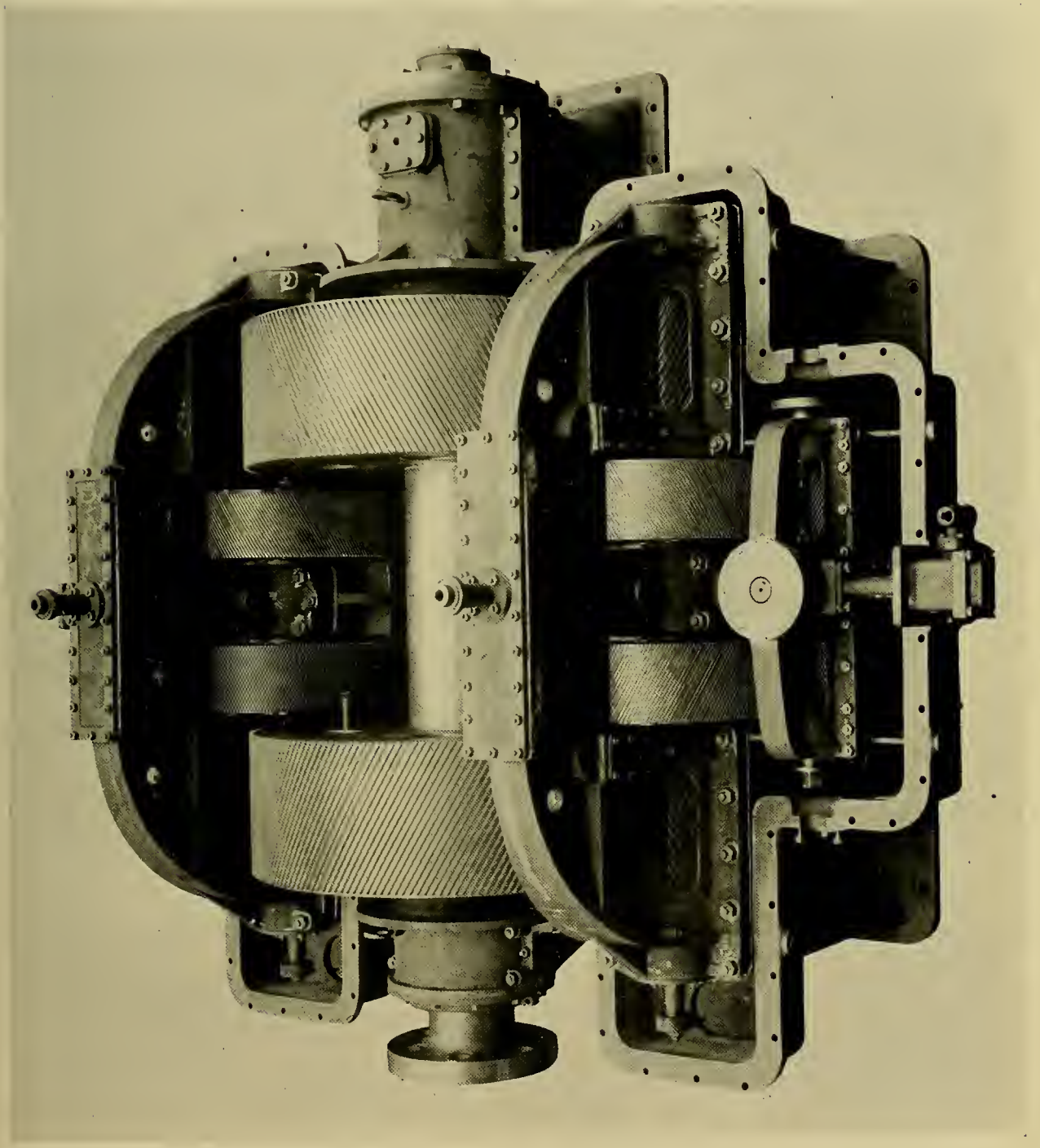

Fig. 6.—Double Pinion Double Reduction Gear.

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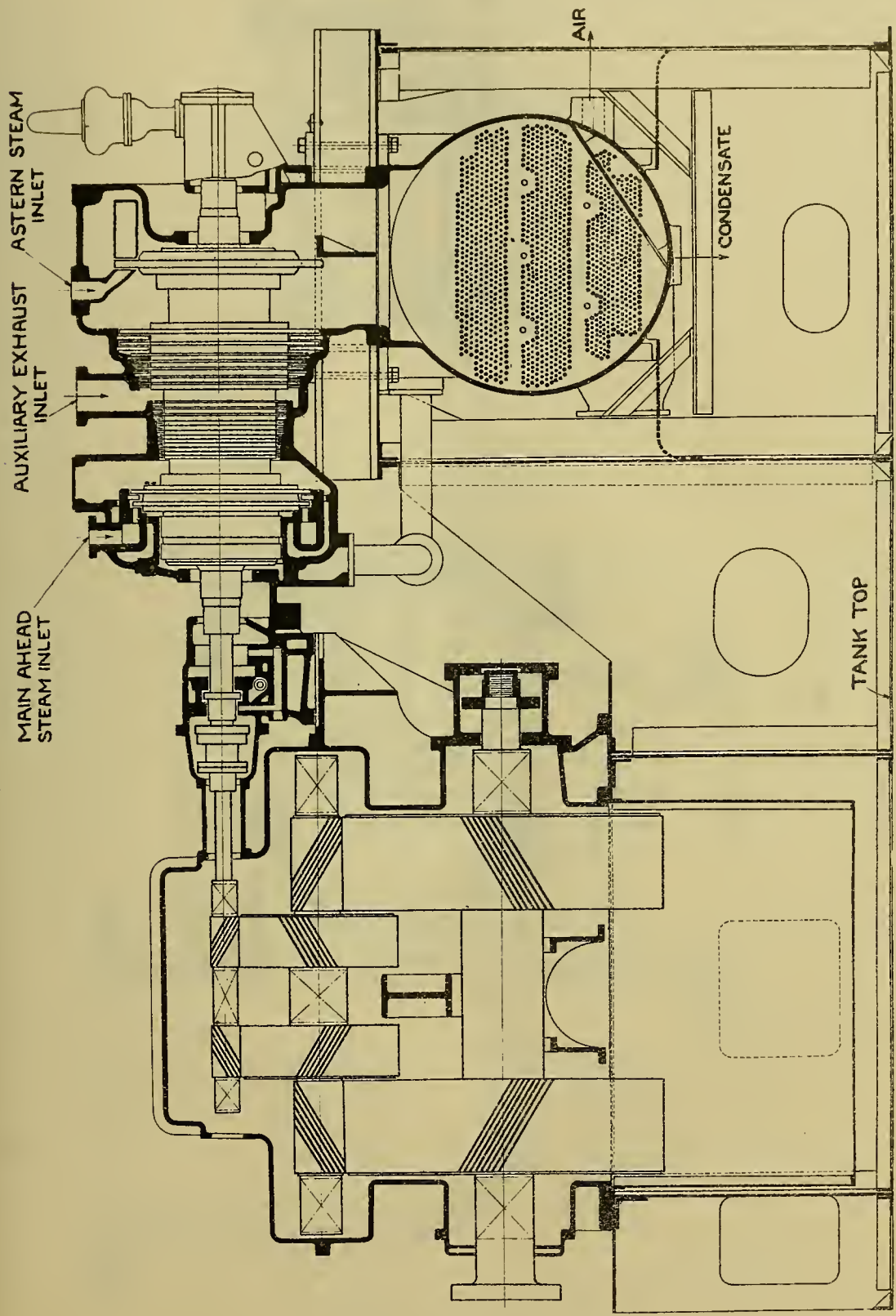

Fig. 7 - Single Turbine Installation (Submarine Boat).

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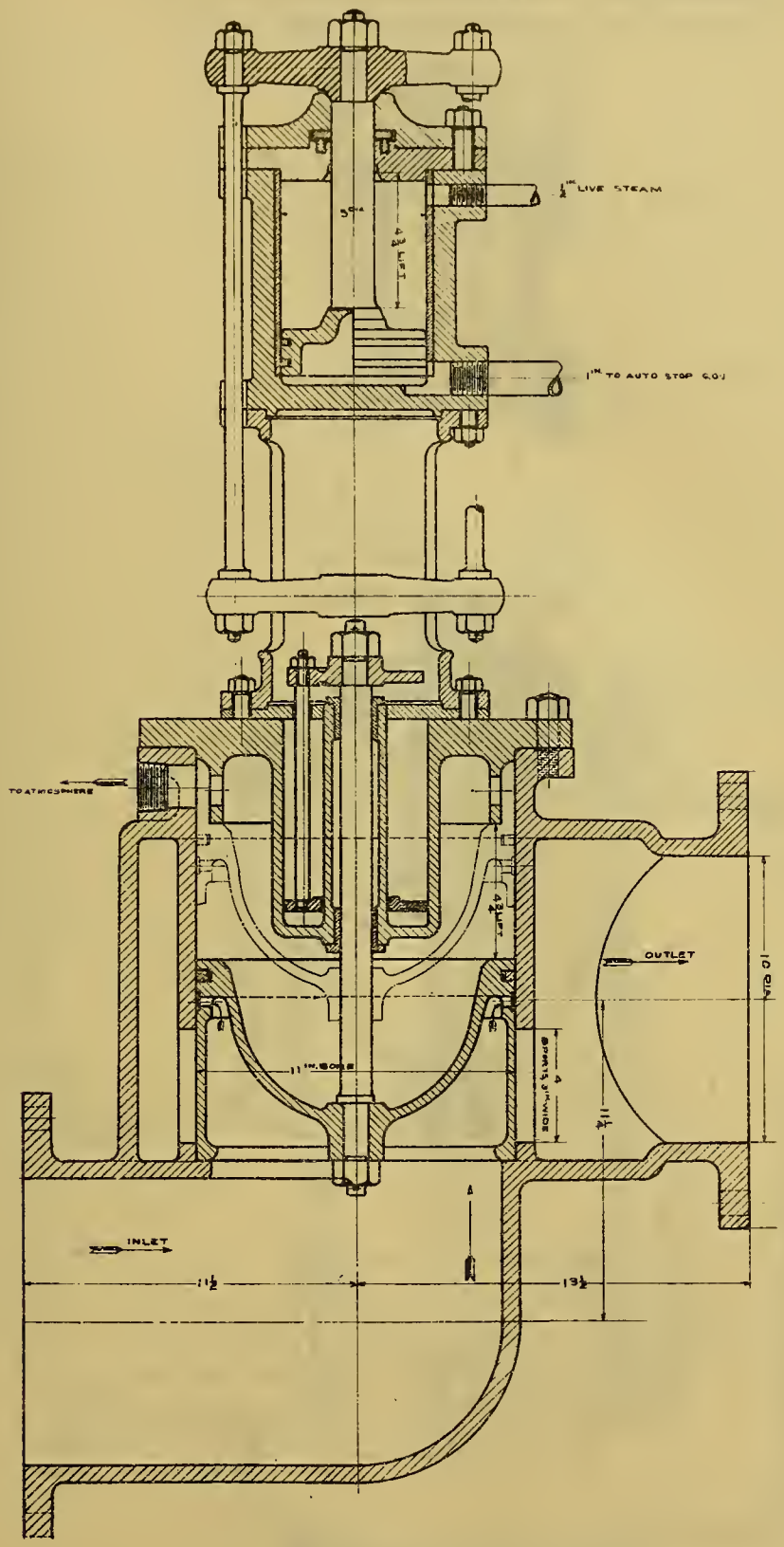

Fig. 8 - Heat Balance Valve (for Flow to Turbine Only).

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To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

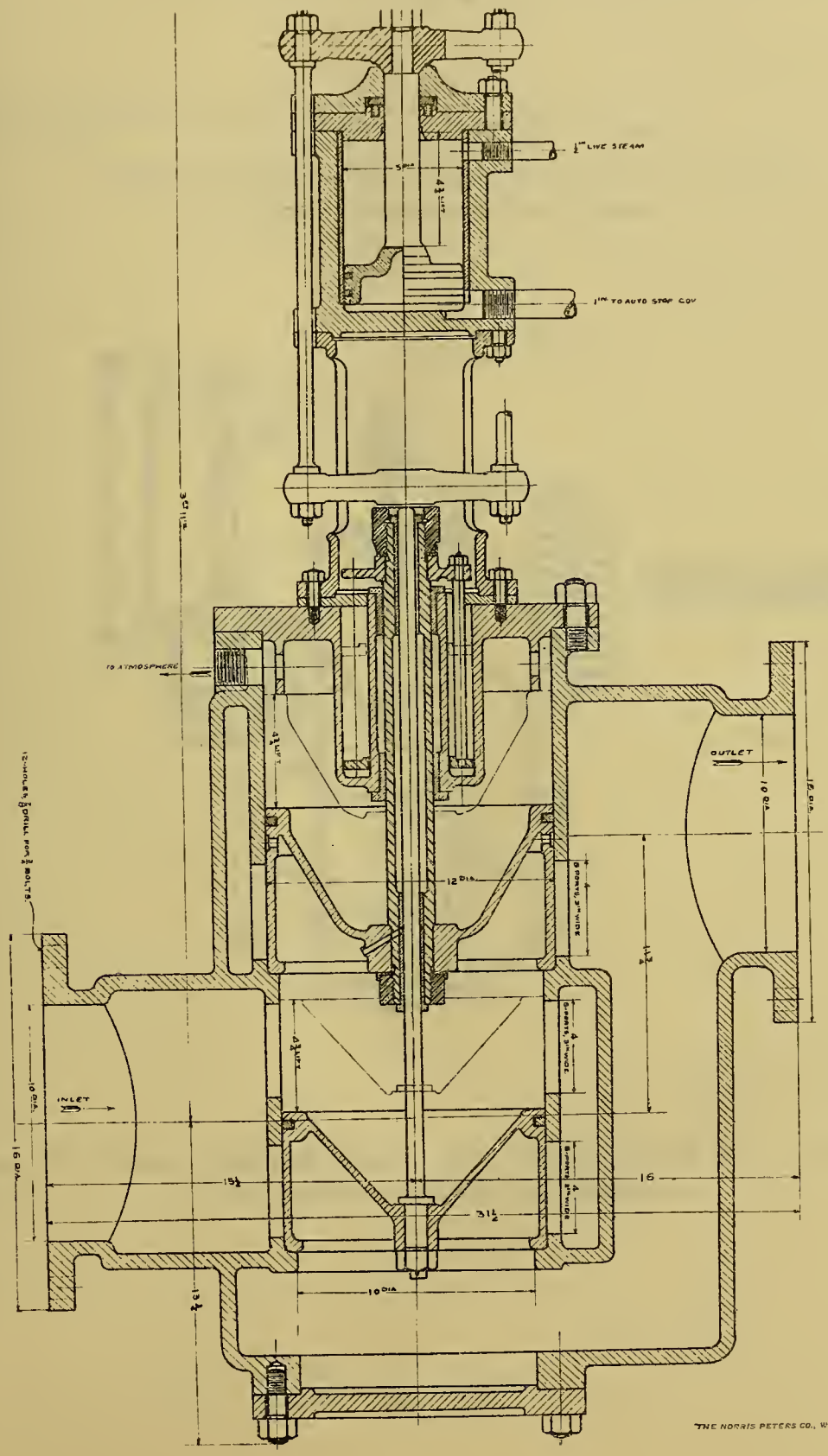

Fig. 9 - Heat Balance Valve (for Flow To and From Turbine).

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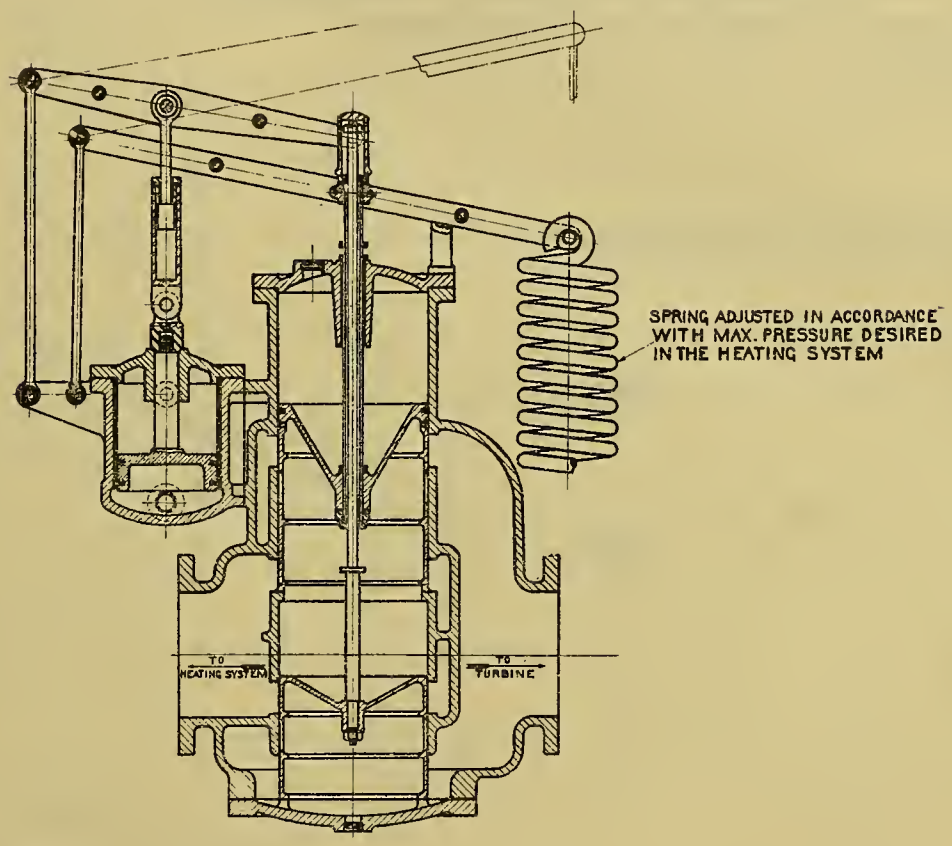

Fig. 10 - Heat Balance Valve (for Flow To and From Turbine with Pressure Limiting Device).

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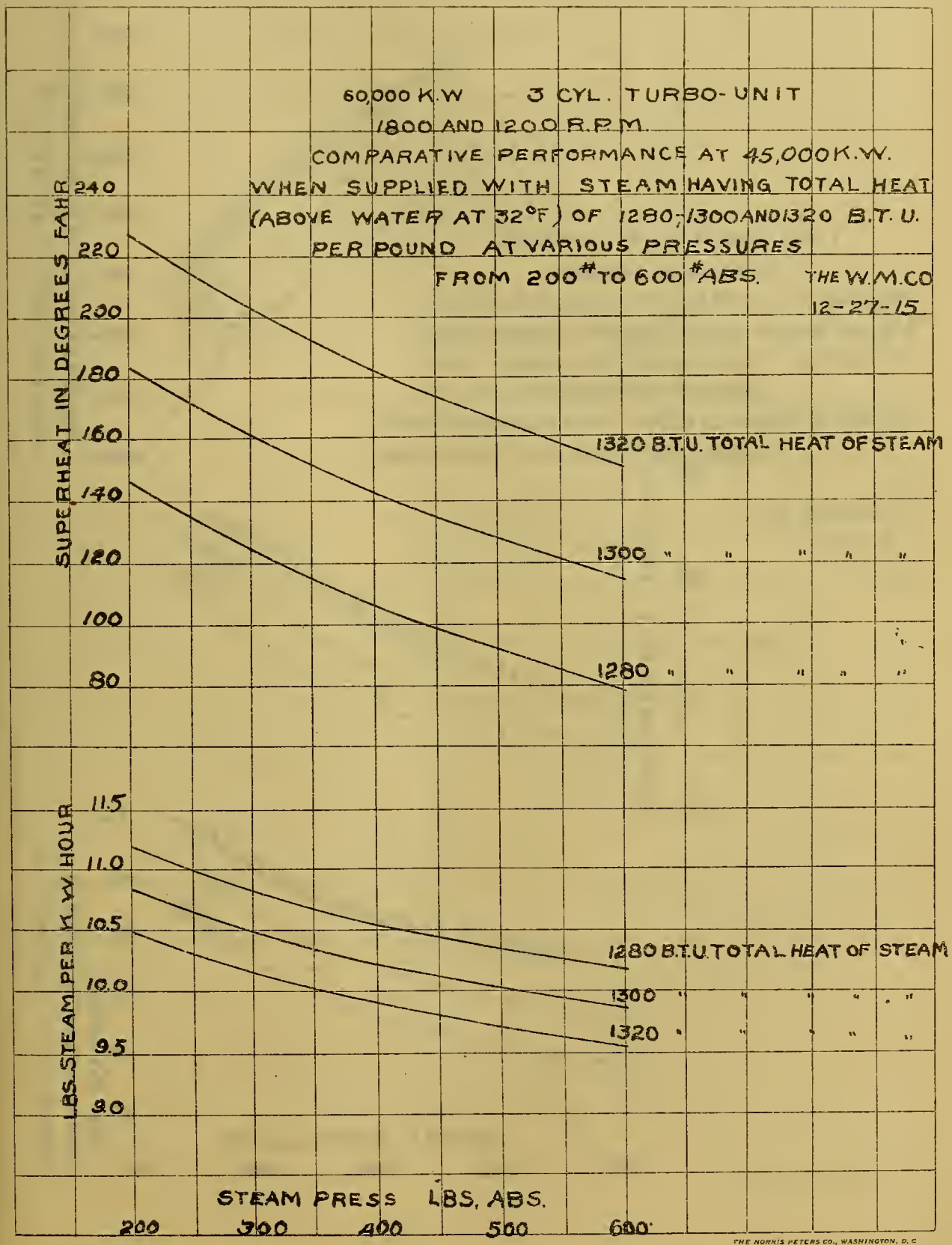

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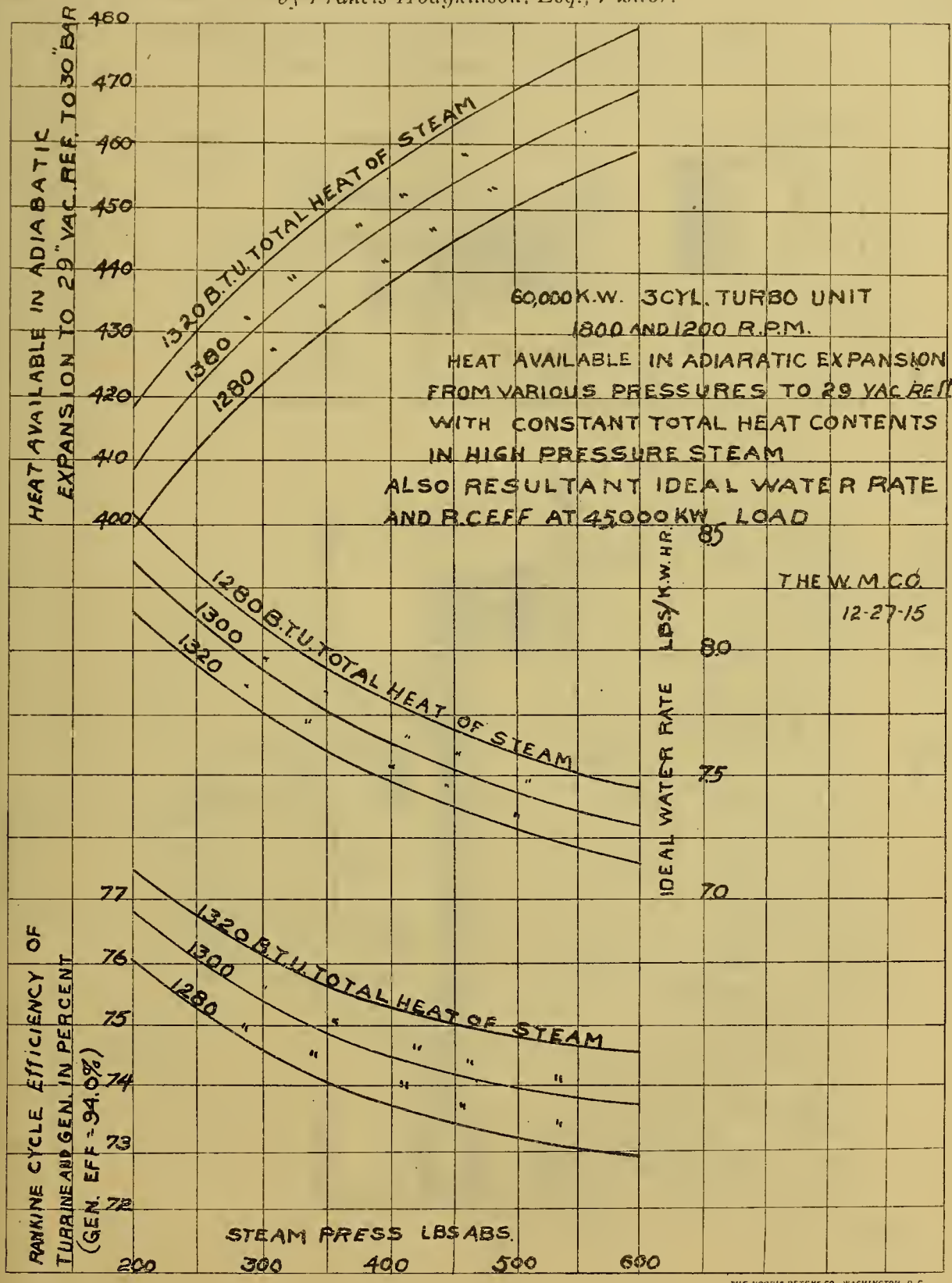
To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.



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To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

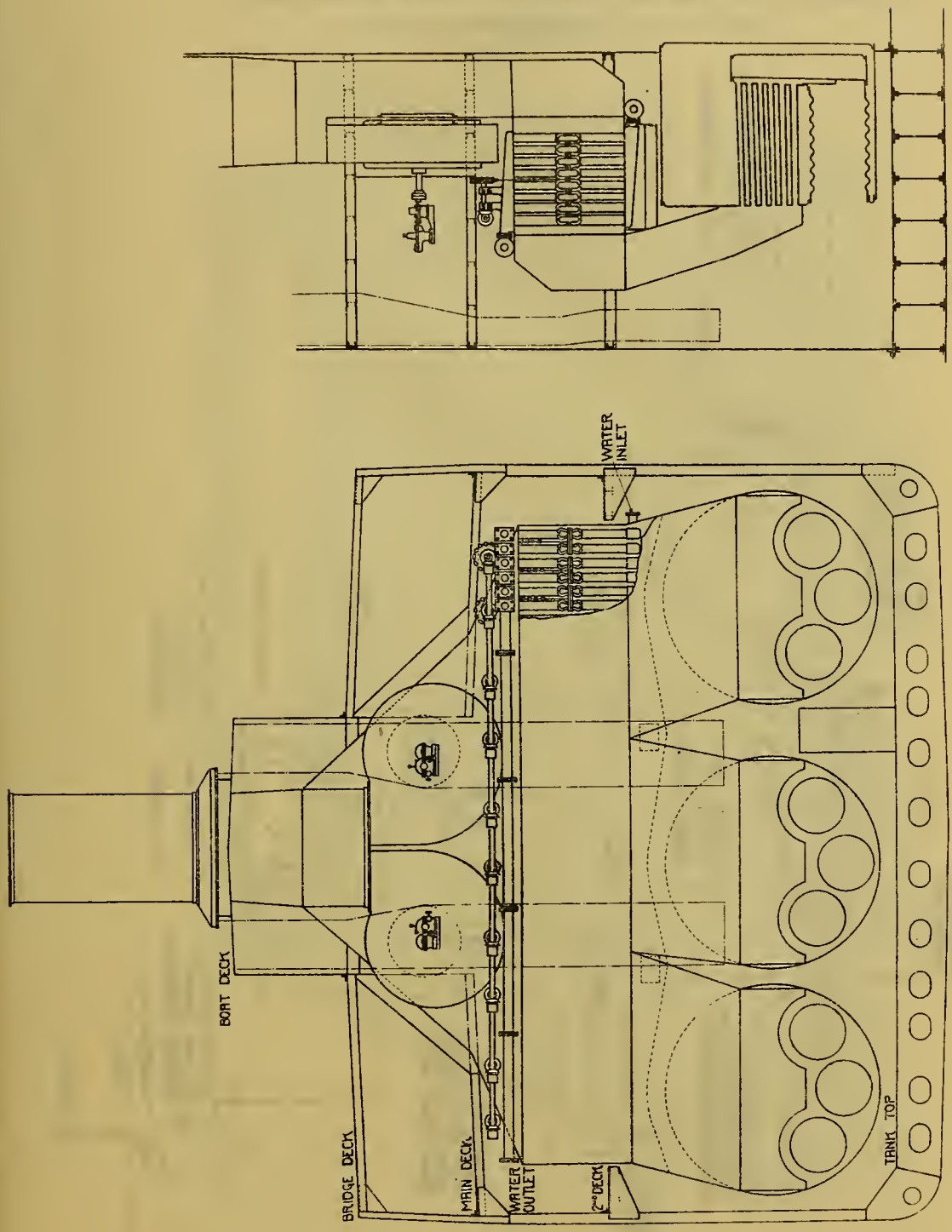

Fig. 13 - Proposed Economizer.

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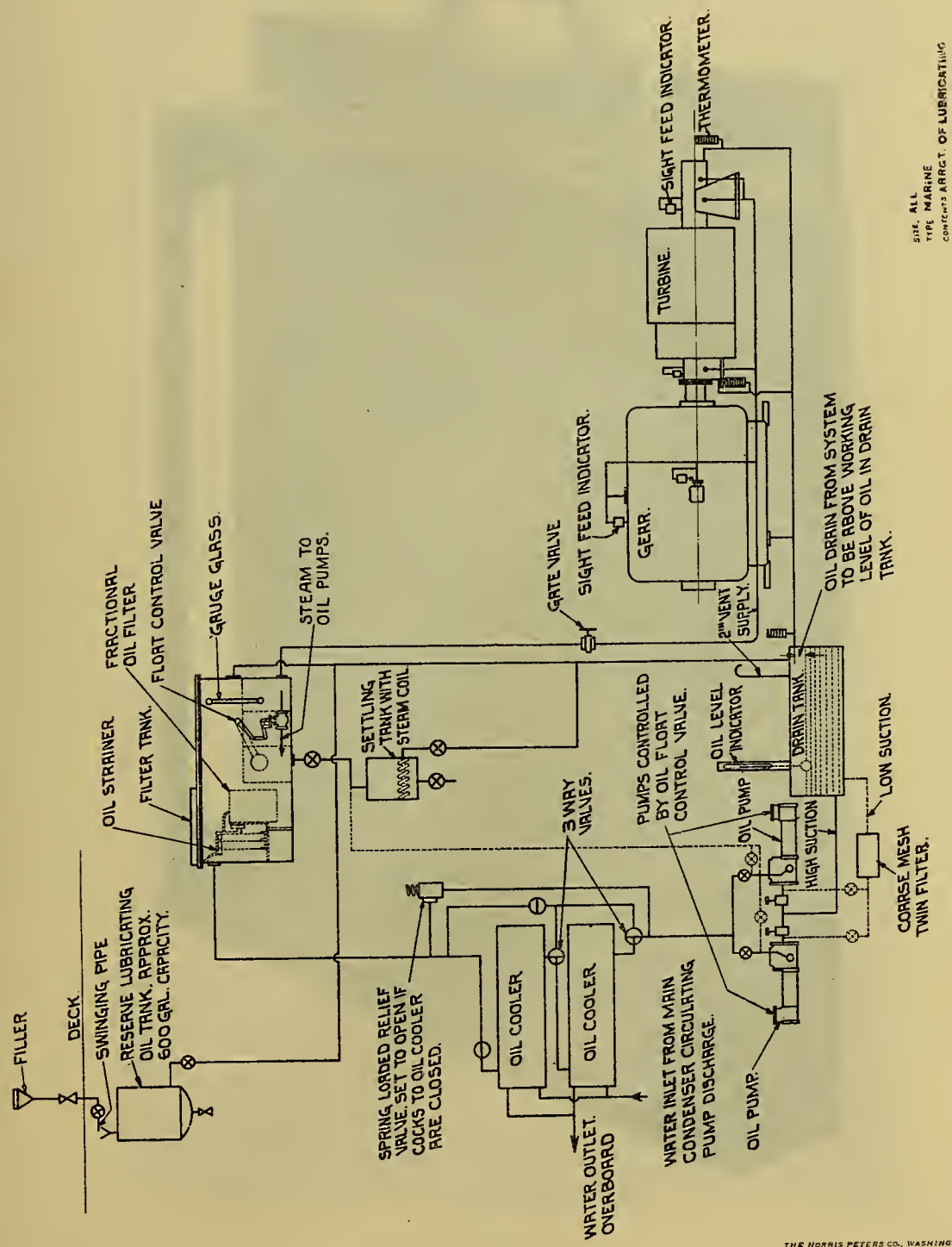

Fig. 14 - Ideal Oiling System.

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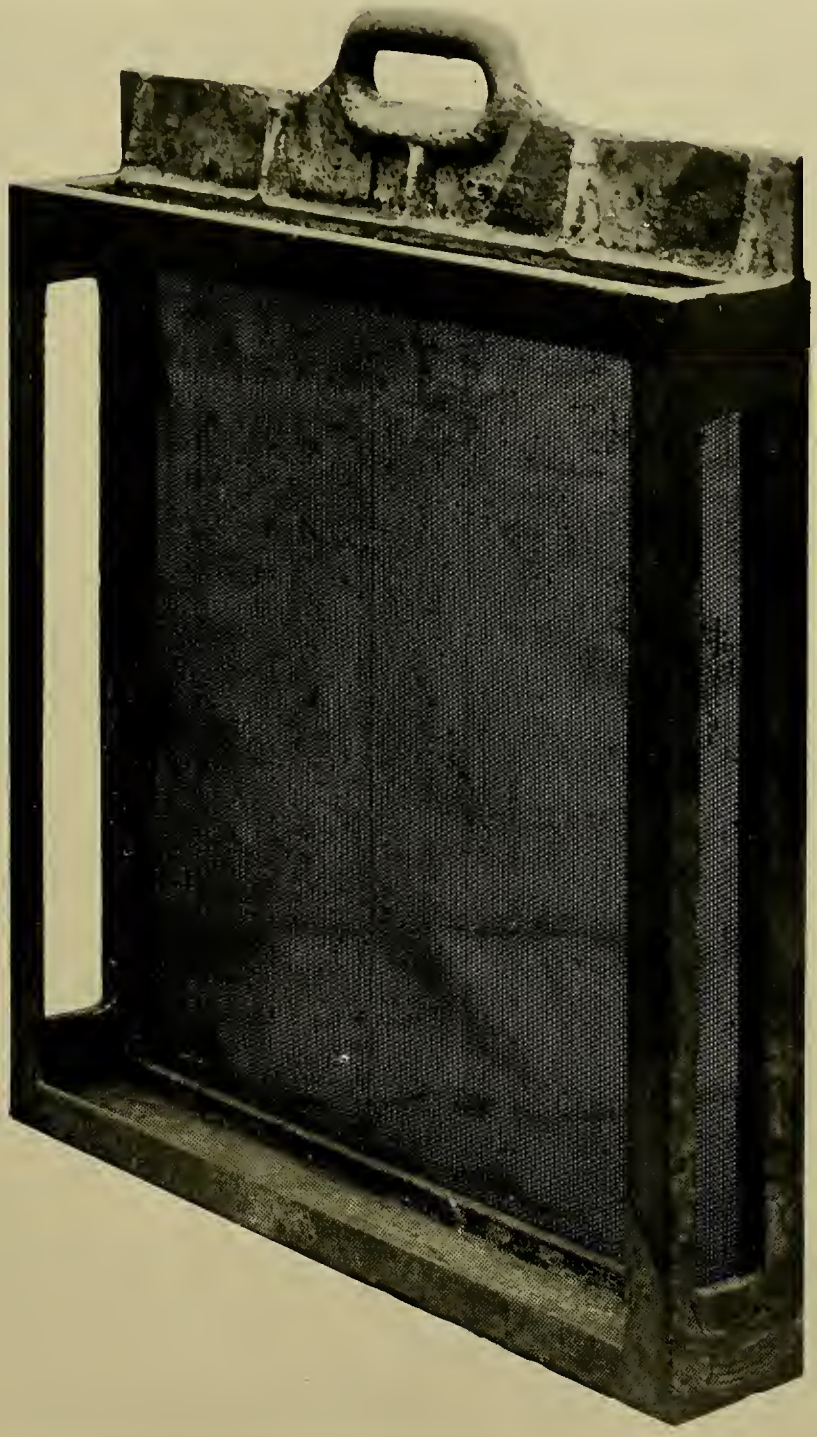

Fig. 15.—An Oil Strainer.

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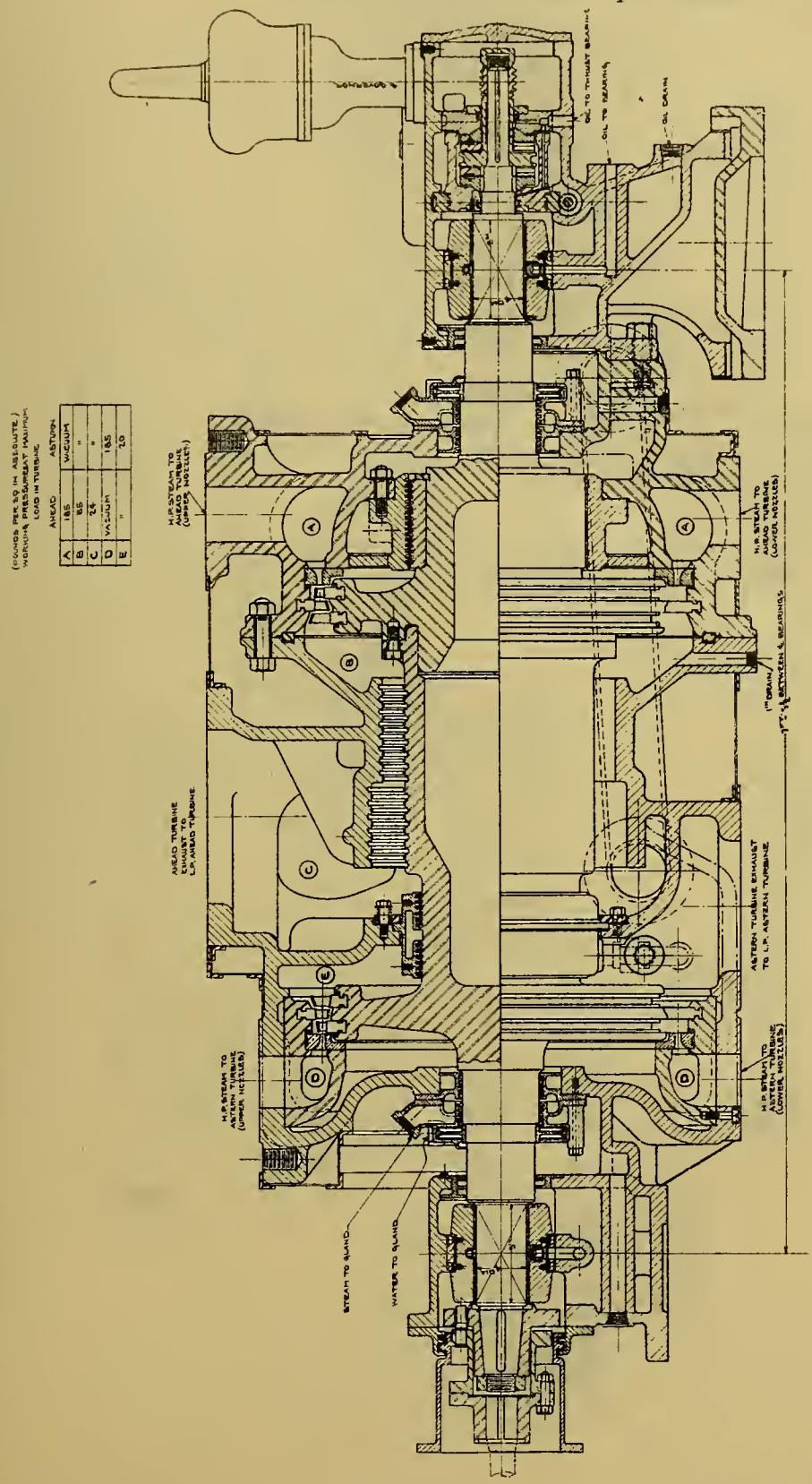

Fig. 16 - H. P. Element of Cross-Compound Turbine.

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To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

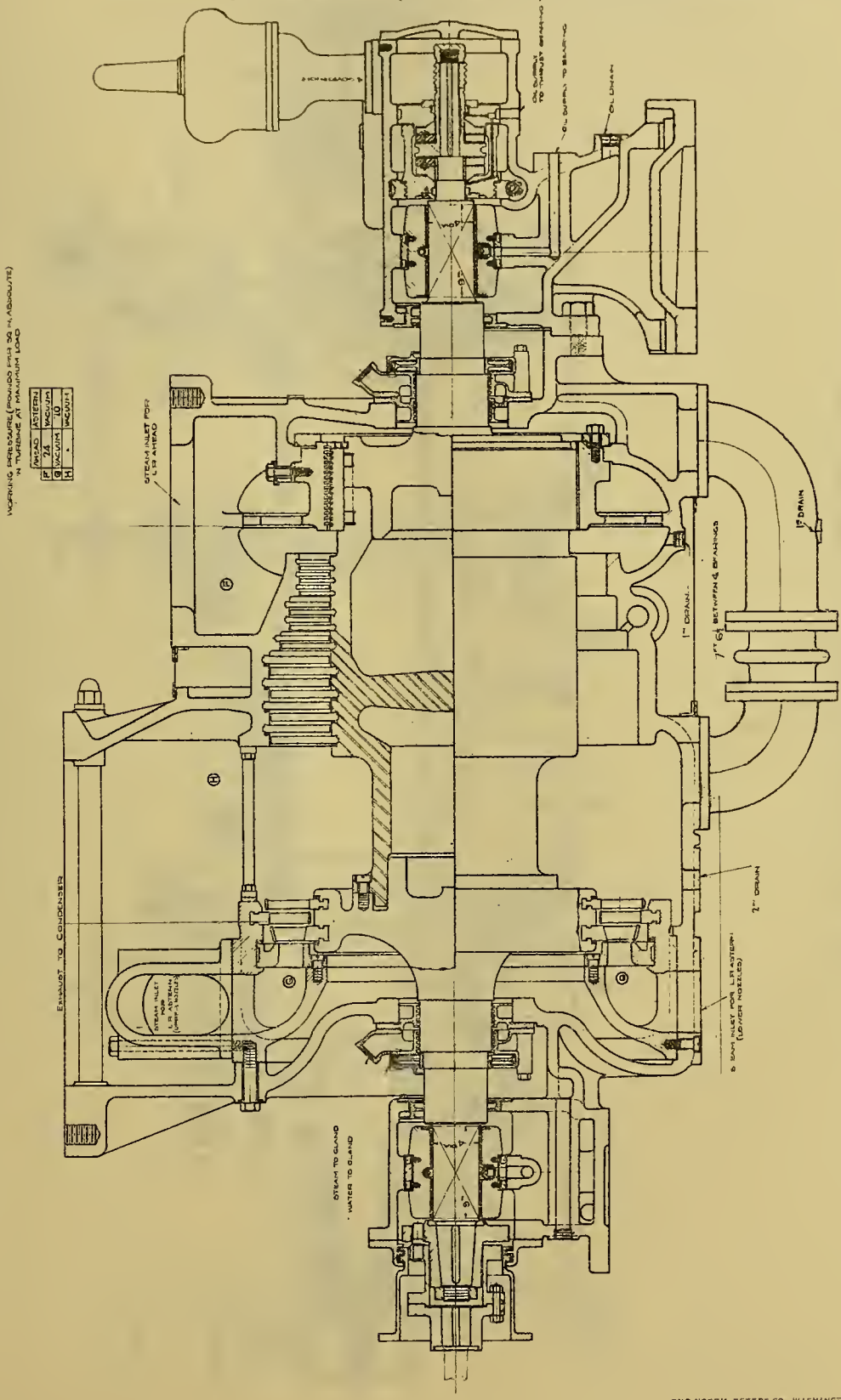

Fig. 17 - L. P. Element of Cross-Compound Turbine.

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To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

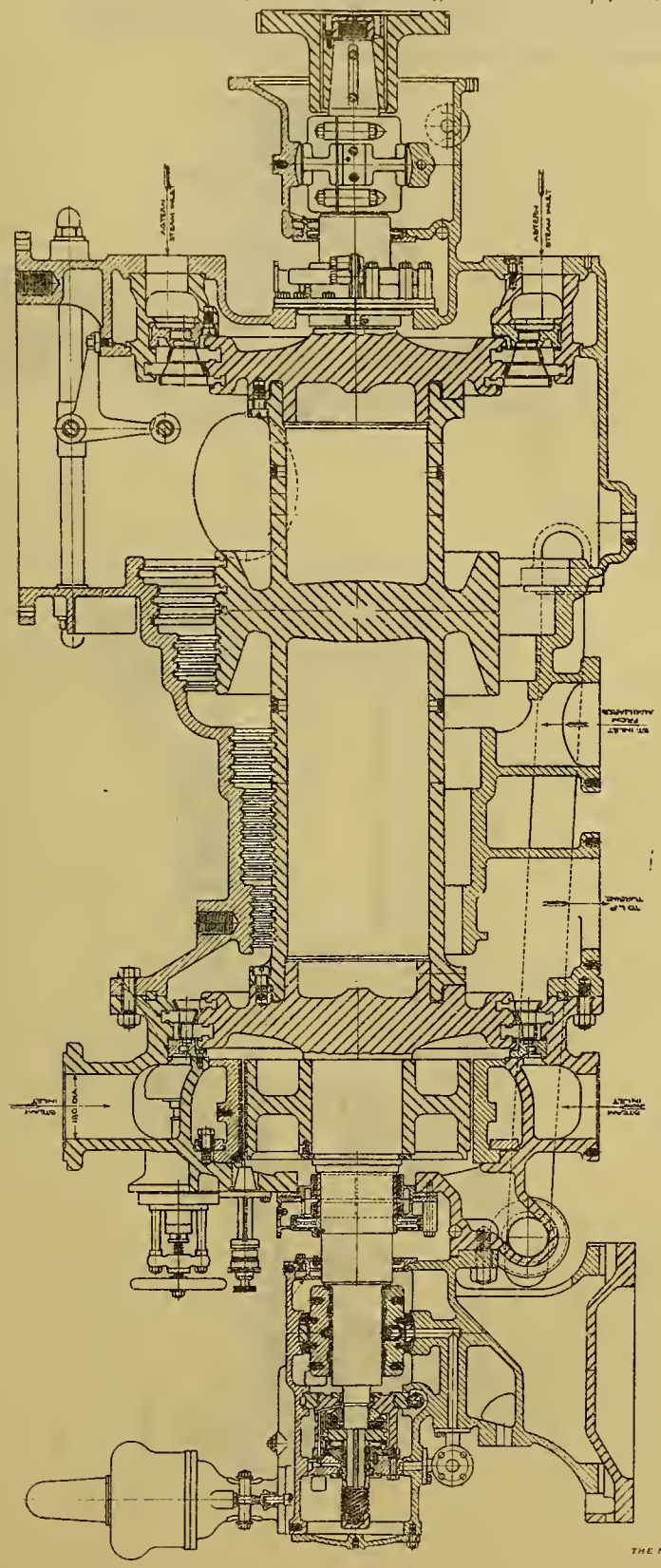

Fig. 18 - H. P. Element of Divided Flow.

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

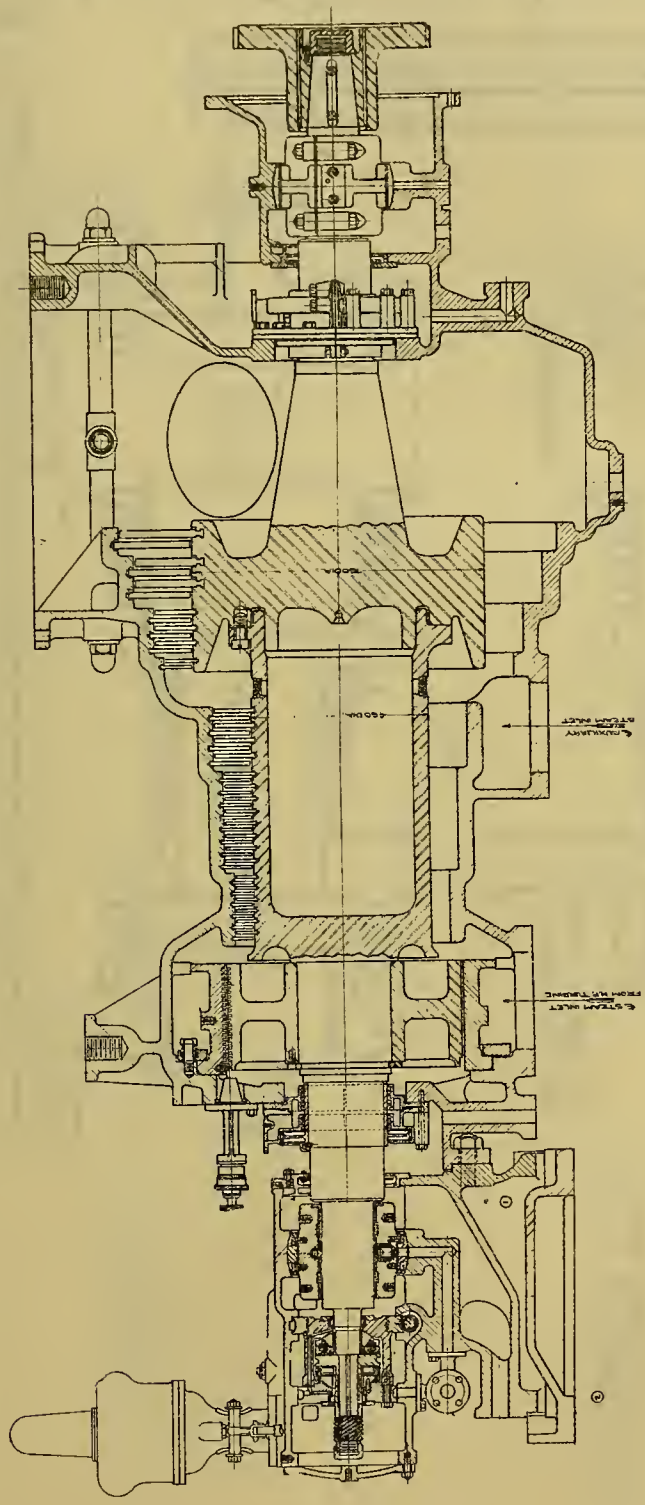

Fig. 19 - L. P. Element of Divided Flow.

THE NORRIS PETERS CO., WASHINGTON, D. C

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

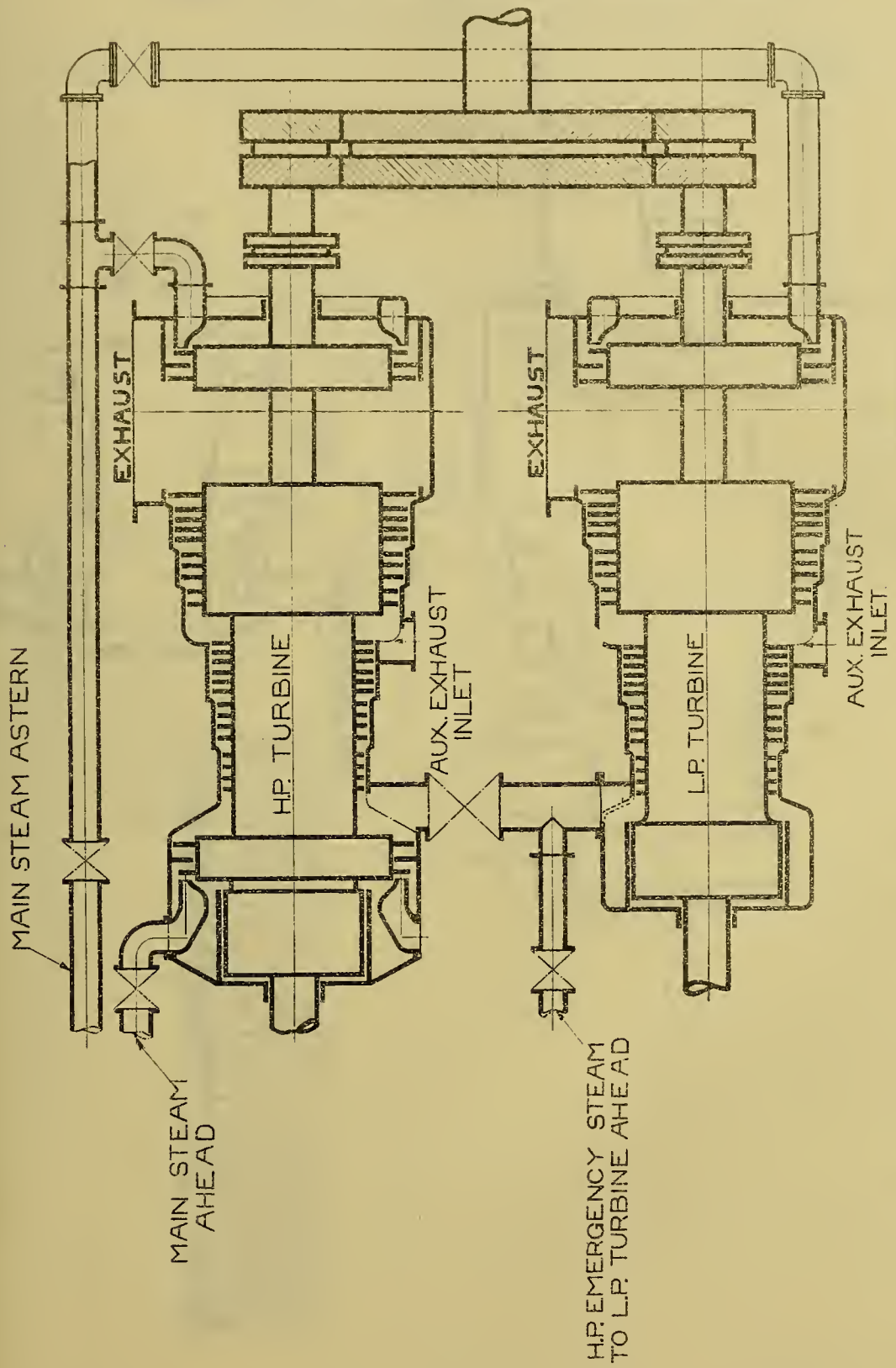

Fig. 20 - General Arrangement of Piping for Divided Flow.

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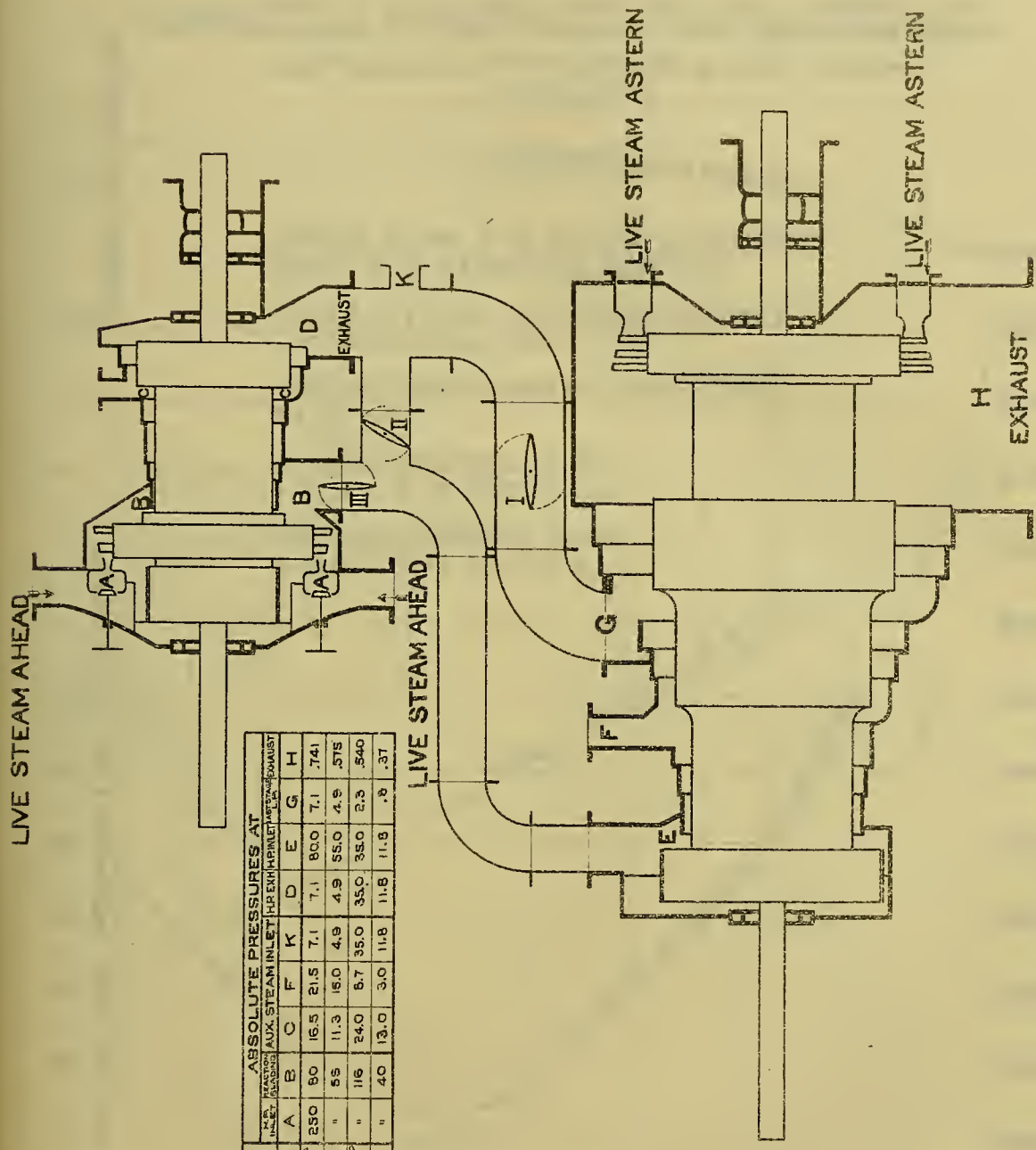
To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.



SHIP KNOTS	TURBINE SPEED H.P.	TURBINE SPEED L.P.	POSITION OF VALVES I	POSITION OF VALVES II	POSITION OF VALVES III	ABSOLUTE PRESSURES AT H.P. INLET (BLADING) A	H.P. INLET (BLADING) B	AUX. STEAM INLET C	F	K	H.P. EXH. D	H.P. INLET E	AFTER H.P. G	EXHAUST H
21	3600	2500	Open	Closed	Open	250	80	16.5	21.5	7.1	7.1	80.0	7.1	.741
19	3190	2208	"	"	"	"	55	11.3	15.0	4.9	4.9	55.0	4.9	.575
15	2440	1695	Closed	Open	Closed	"	116	24.0	6.7	35.0	35.0	35.0	2.3	.540
10	1665	1156	"	"	"	"	40	13.0	3.0	11.8	11.8	11.8	.8	.37

Fig. 21 - General Arrangement of Series Divided Flow.

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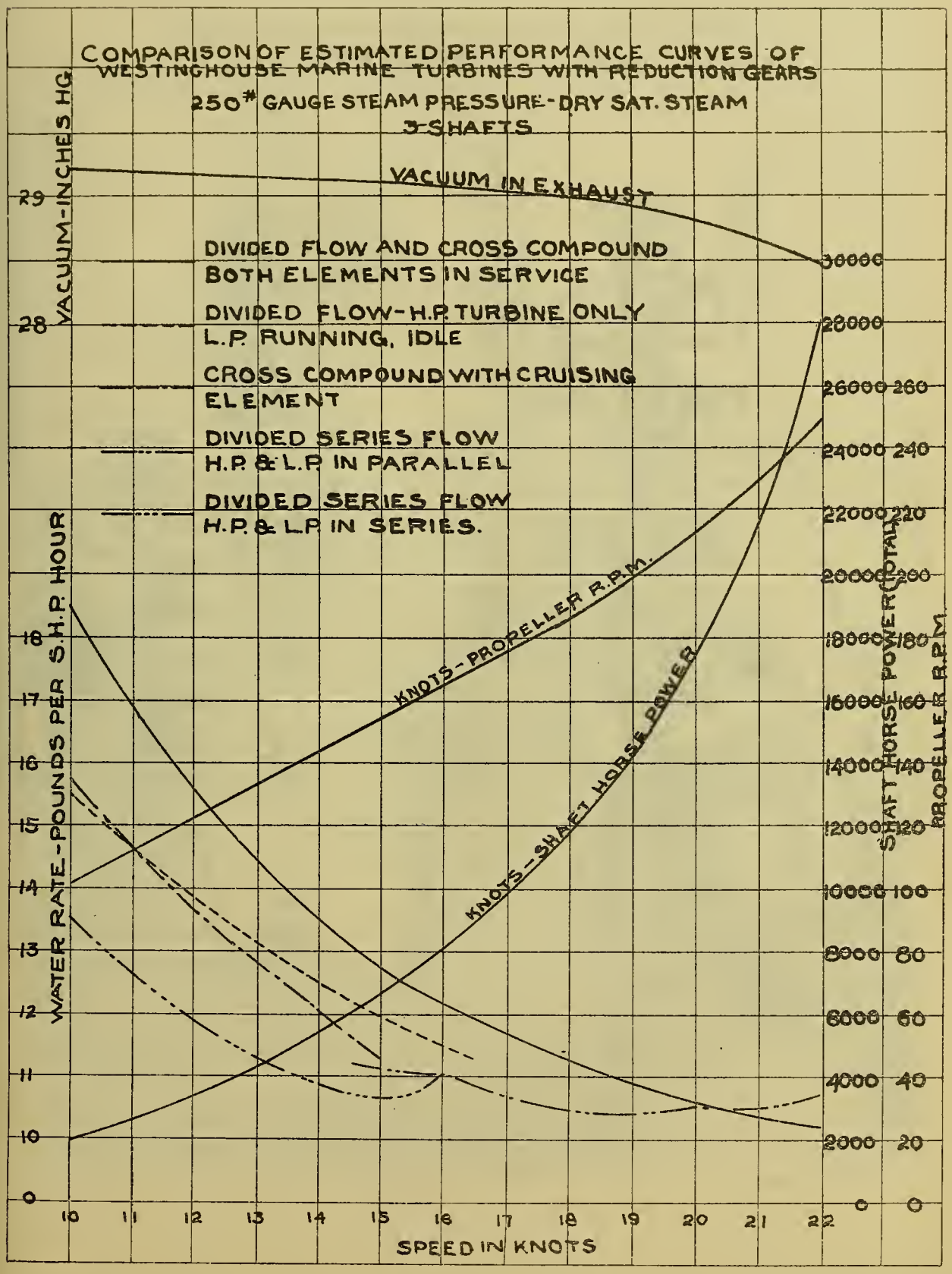
To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.



THE NORRIS PETERS CO. WASHINGTON, D. C.

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

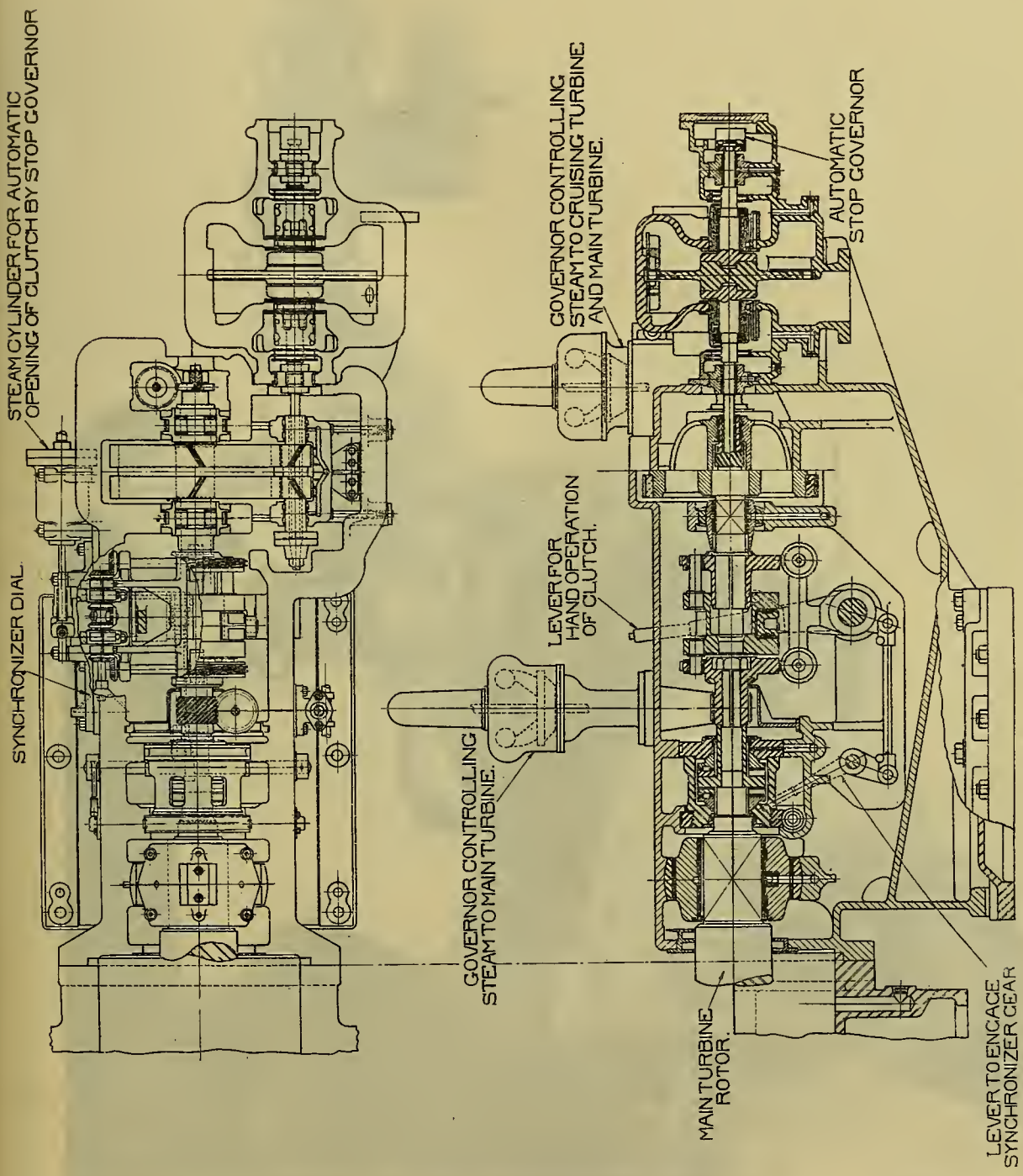


Fig. 23 - Cruising Turbine Arrangement.

THE NORRIS PETERS CO. WASH. D. C.

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

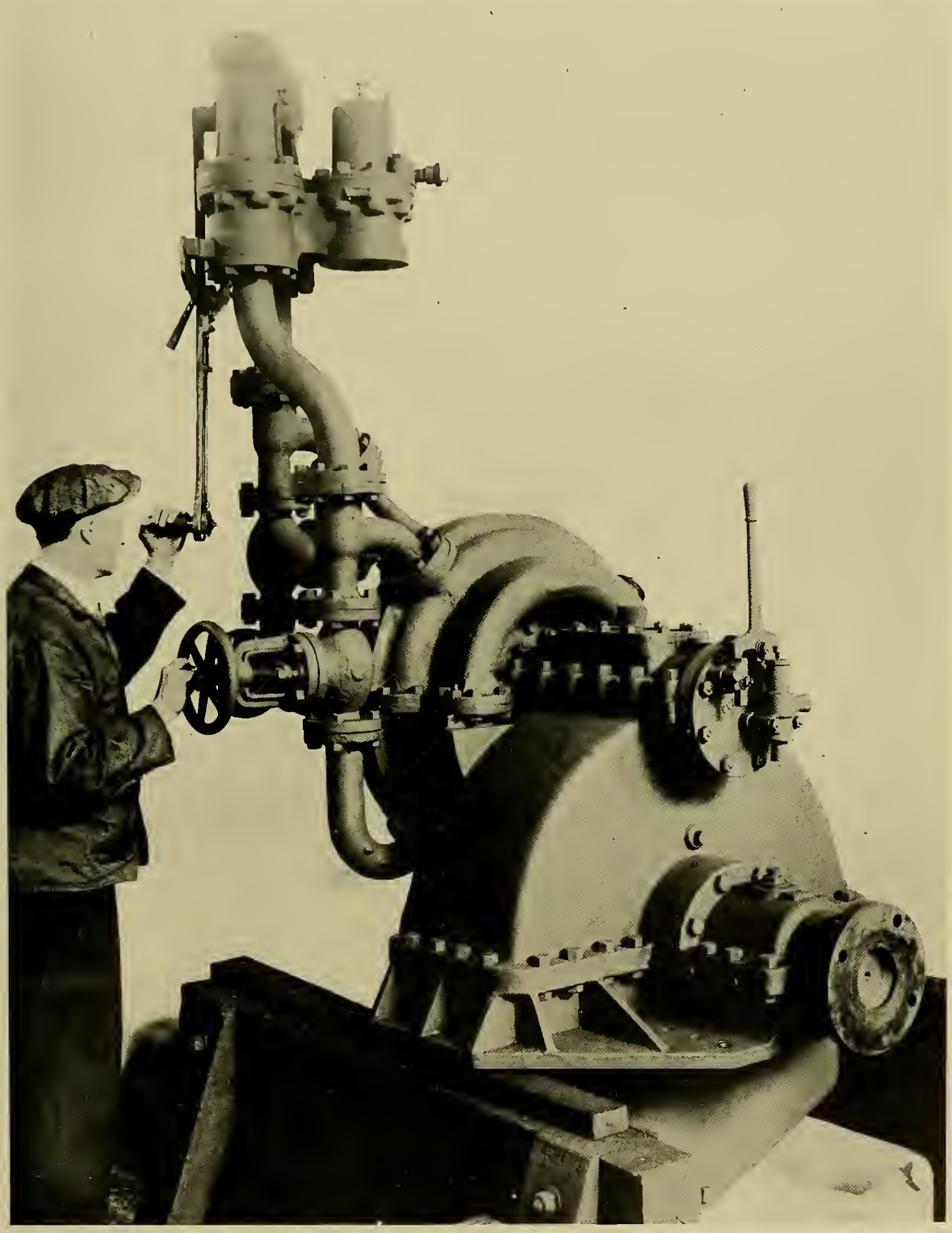


Fig. 24.—600 H. P. Submarine Chaser.

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

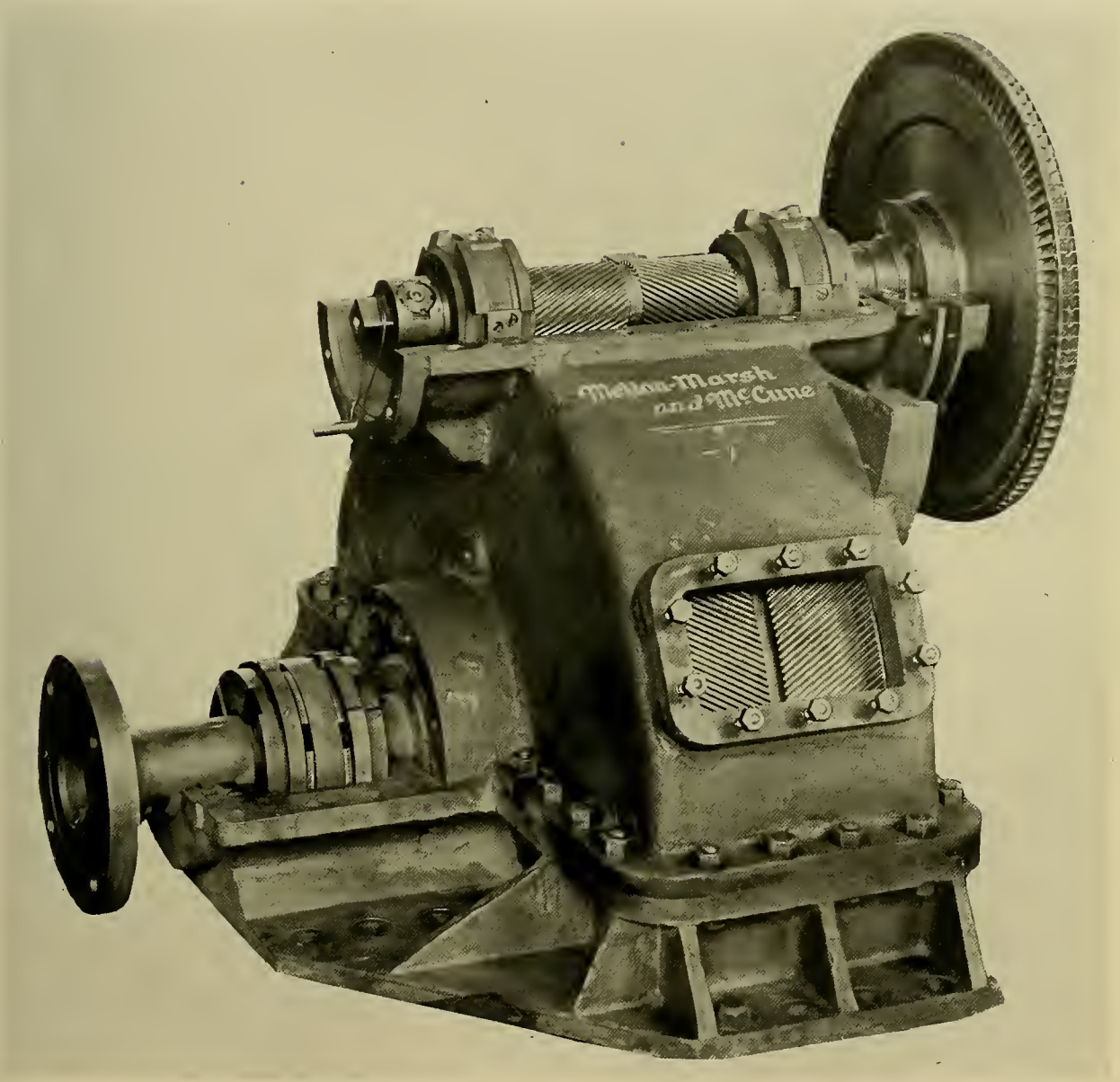


Fig. 25.—600 H. P. Submarine Chaser (Showing Rotating Element).

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

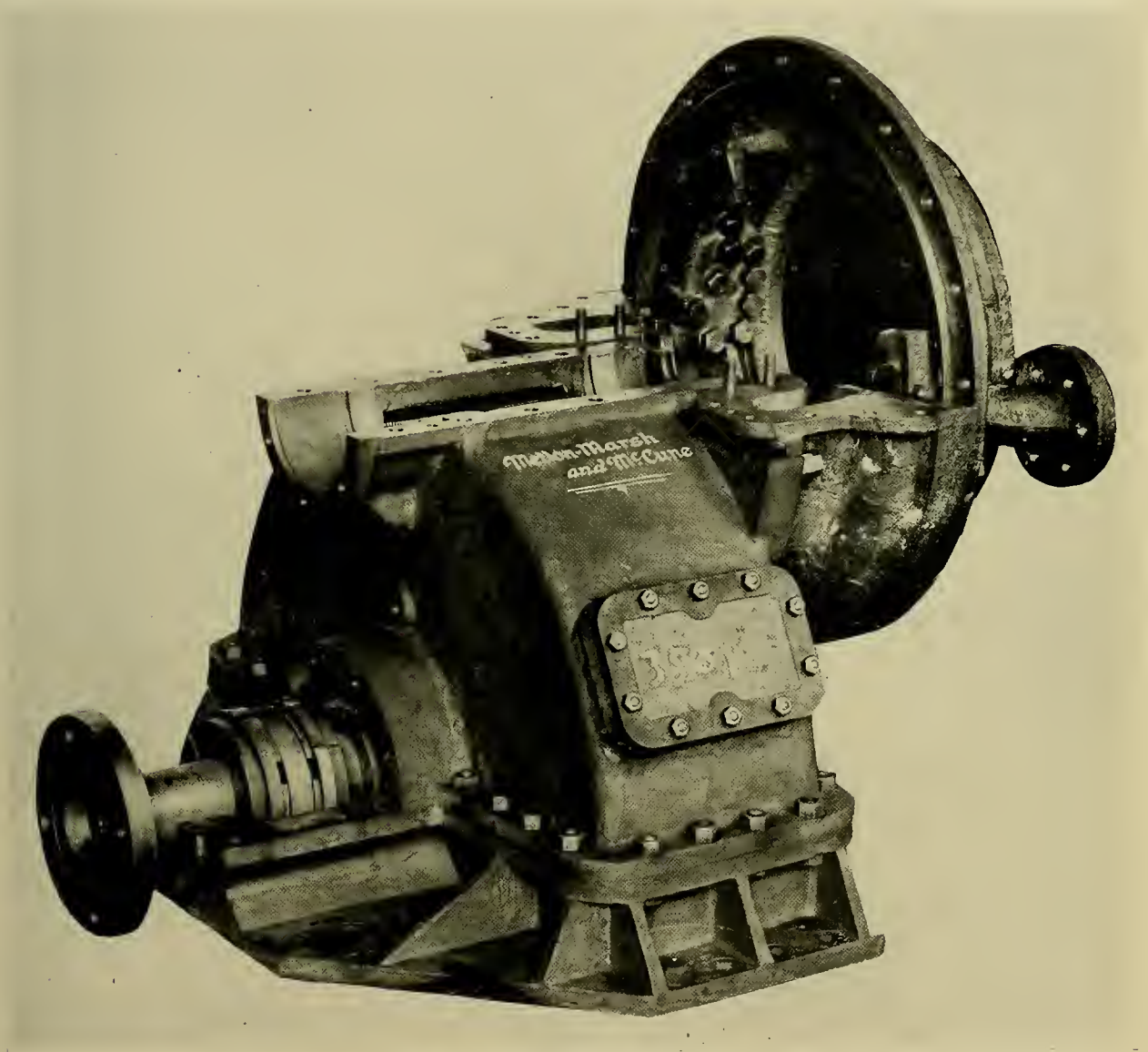


Fig. 26.—600 H. P. Submarine Chaser (Showing Stator).

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor

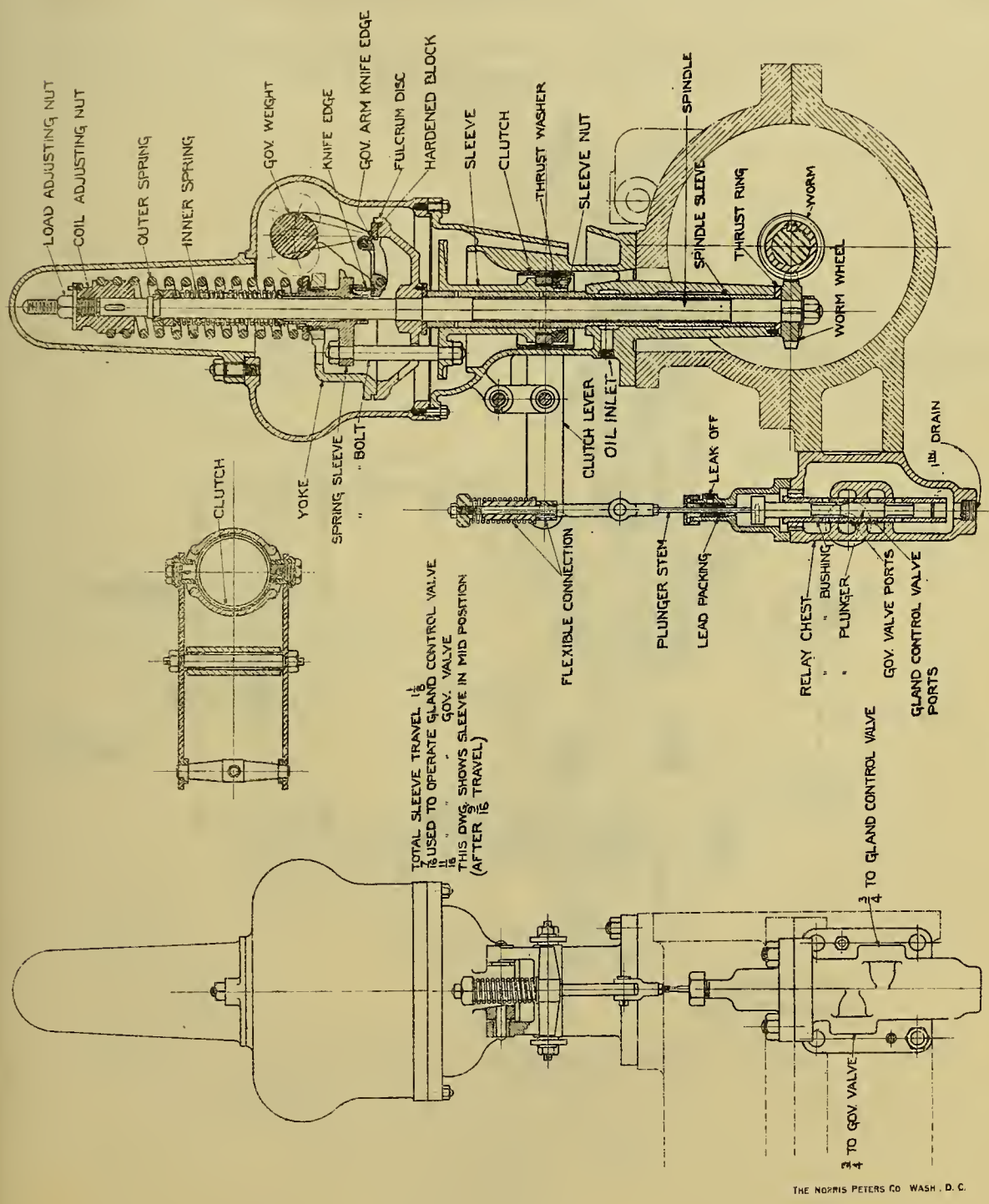


Fig. 27 - Marine Governor.

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

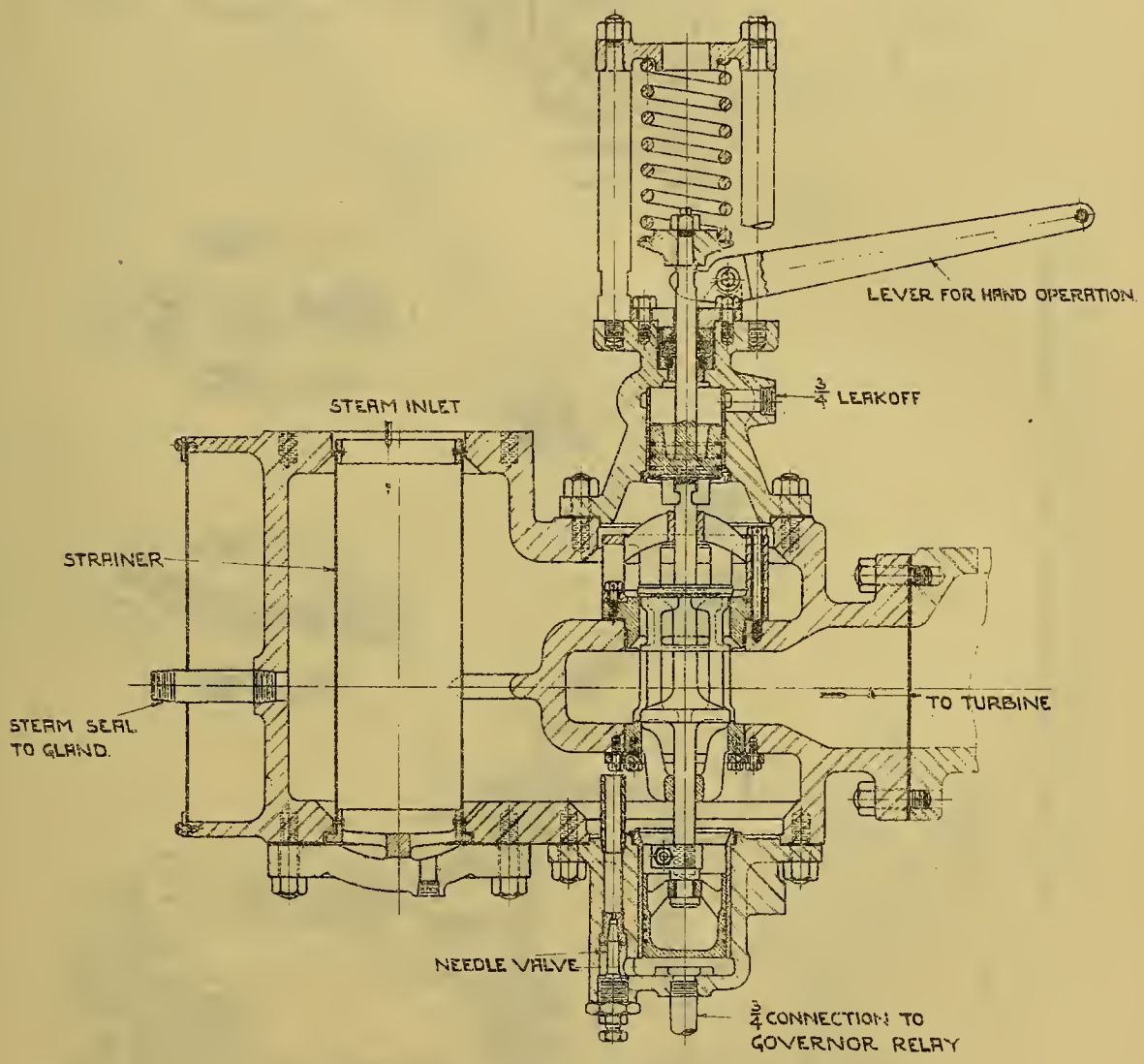


Fig. 28 - Marine Governor Valve.

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

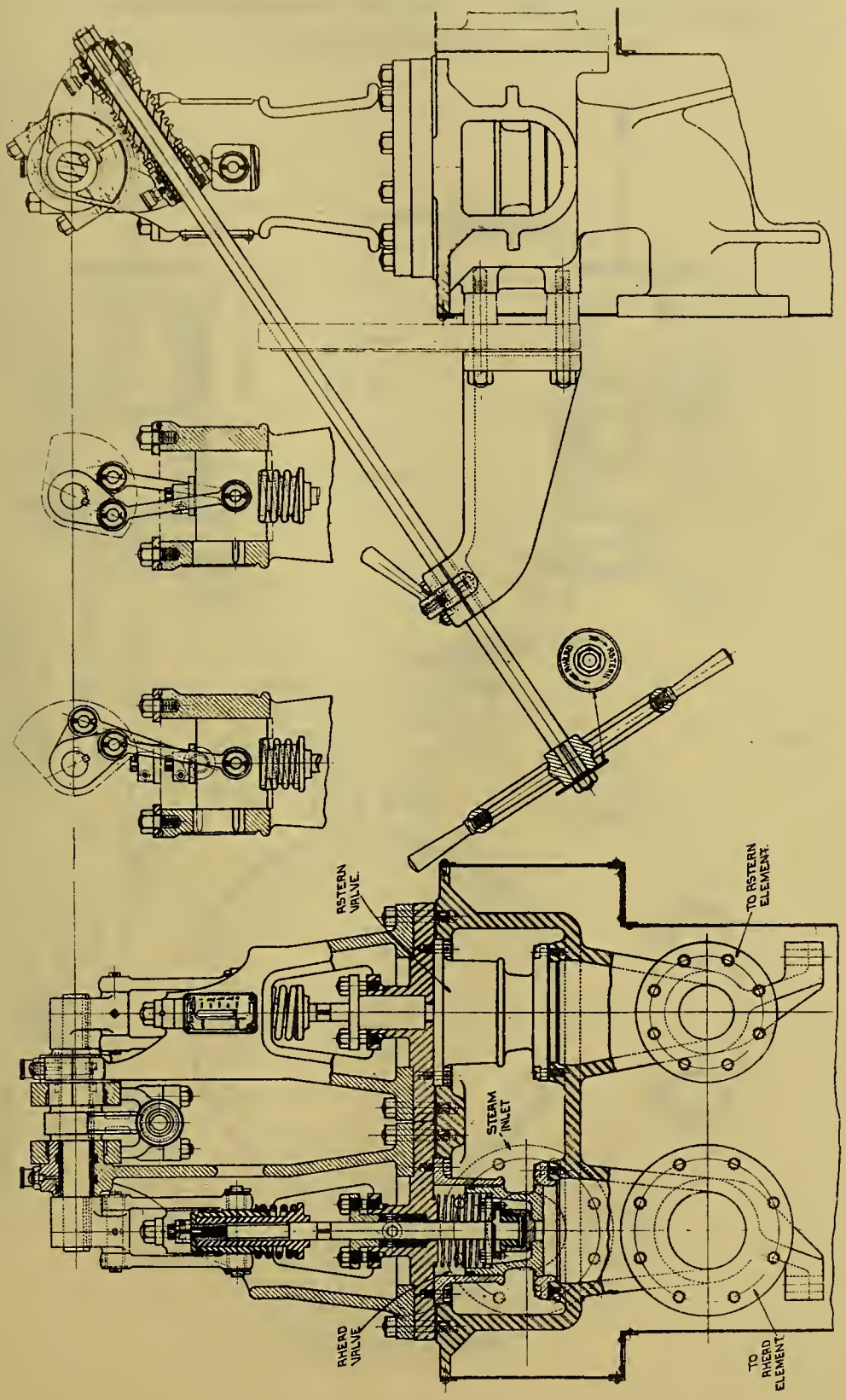


Fig. 29 - Maneuvering Valve Arrangement.

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To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

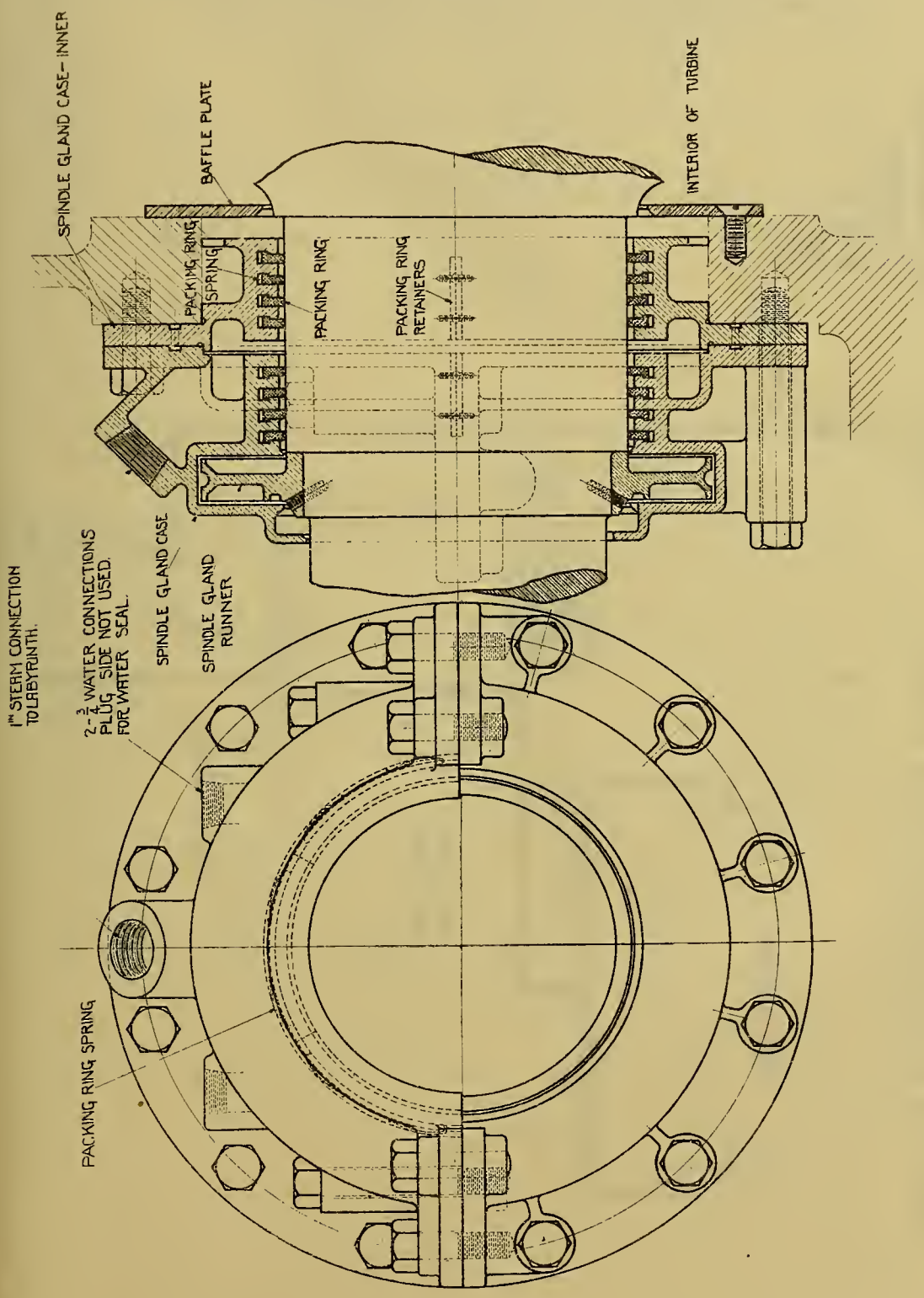

Fig. 30 - Marine Gland.

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Progress in Turbine Ship Propulsion." by Francis Hodgkinson, Esq., Visitor.

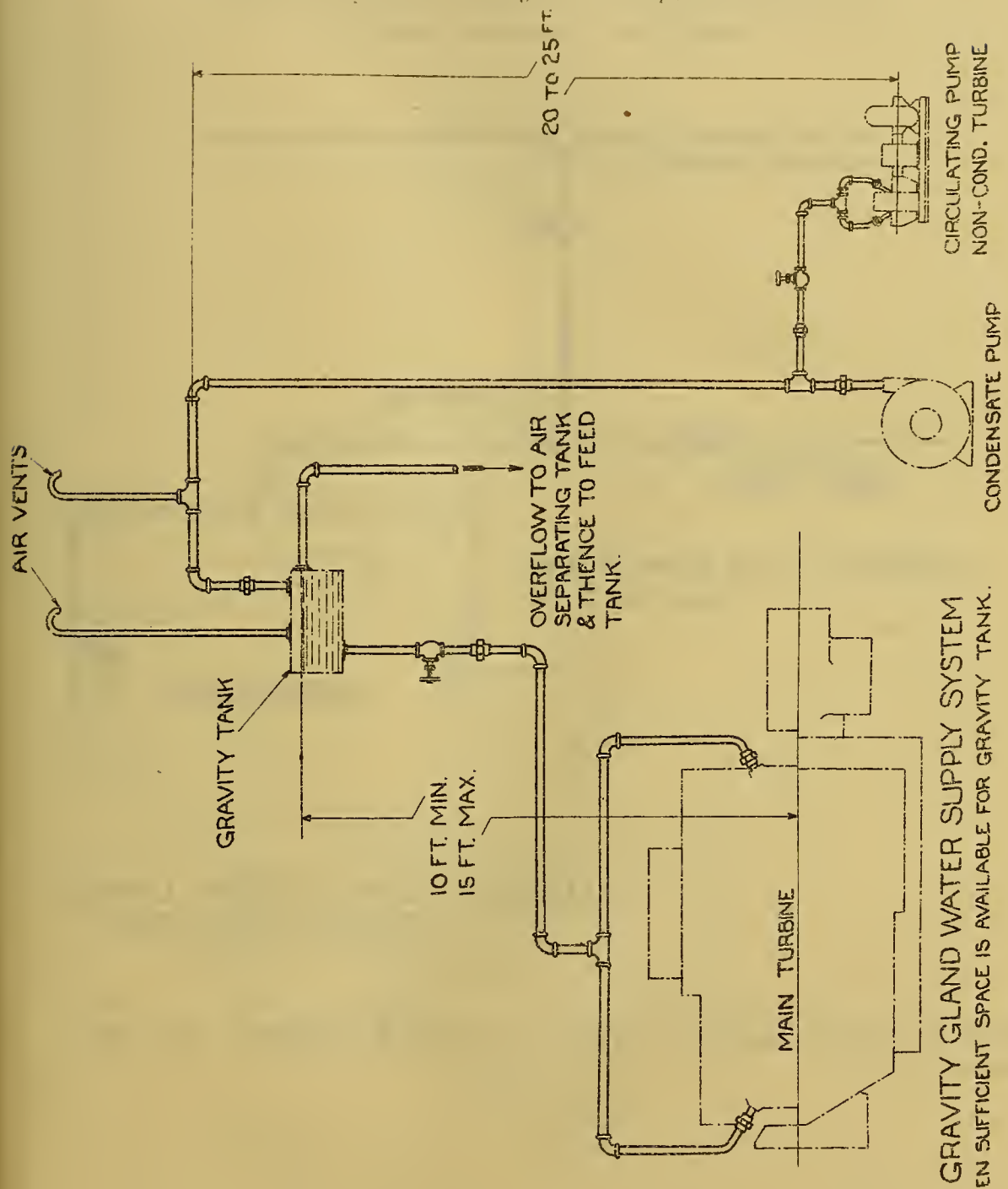

Fig. 31 - Method of Providing Water to Gland (Stand Pipe).

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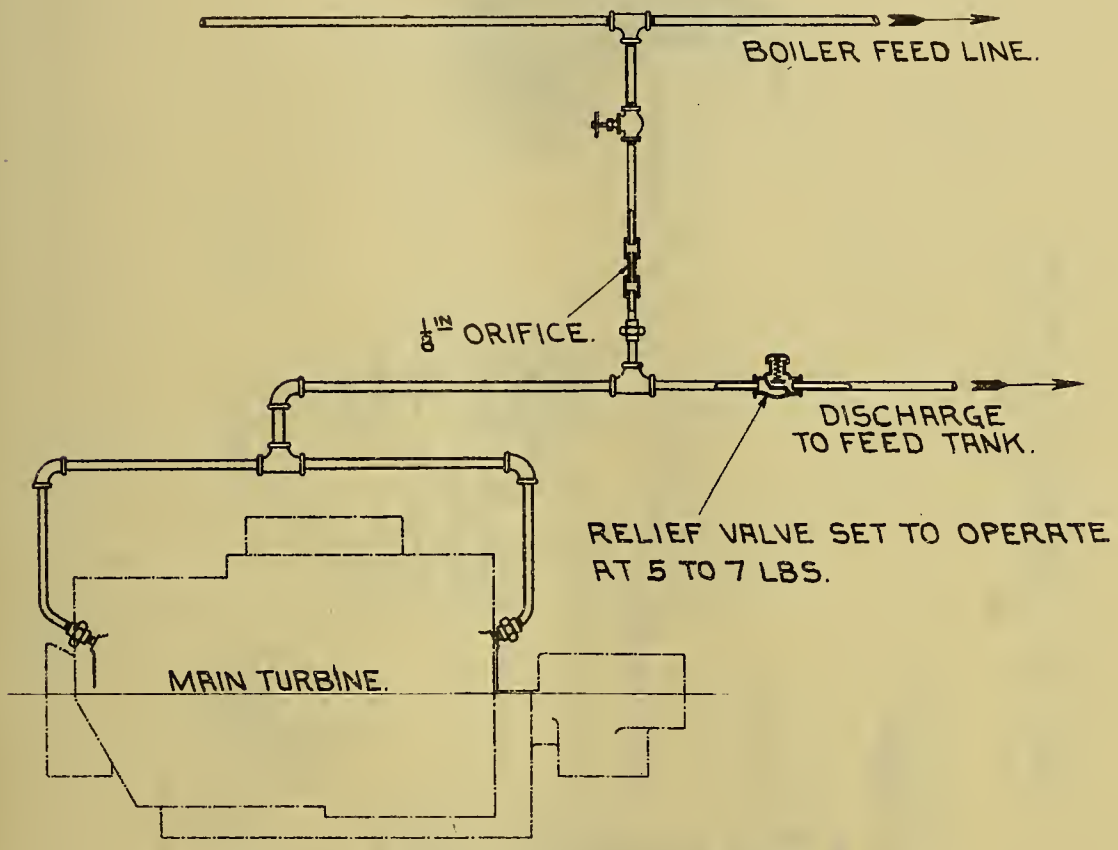
To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.



GLAND WATER SUPPLY SYSTEM.
WHEN SPACE IS LIMITED.

Fig. 32 - Method of Providing Water to Gland (Pressure System).

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To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

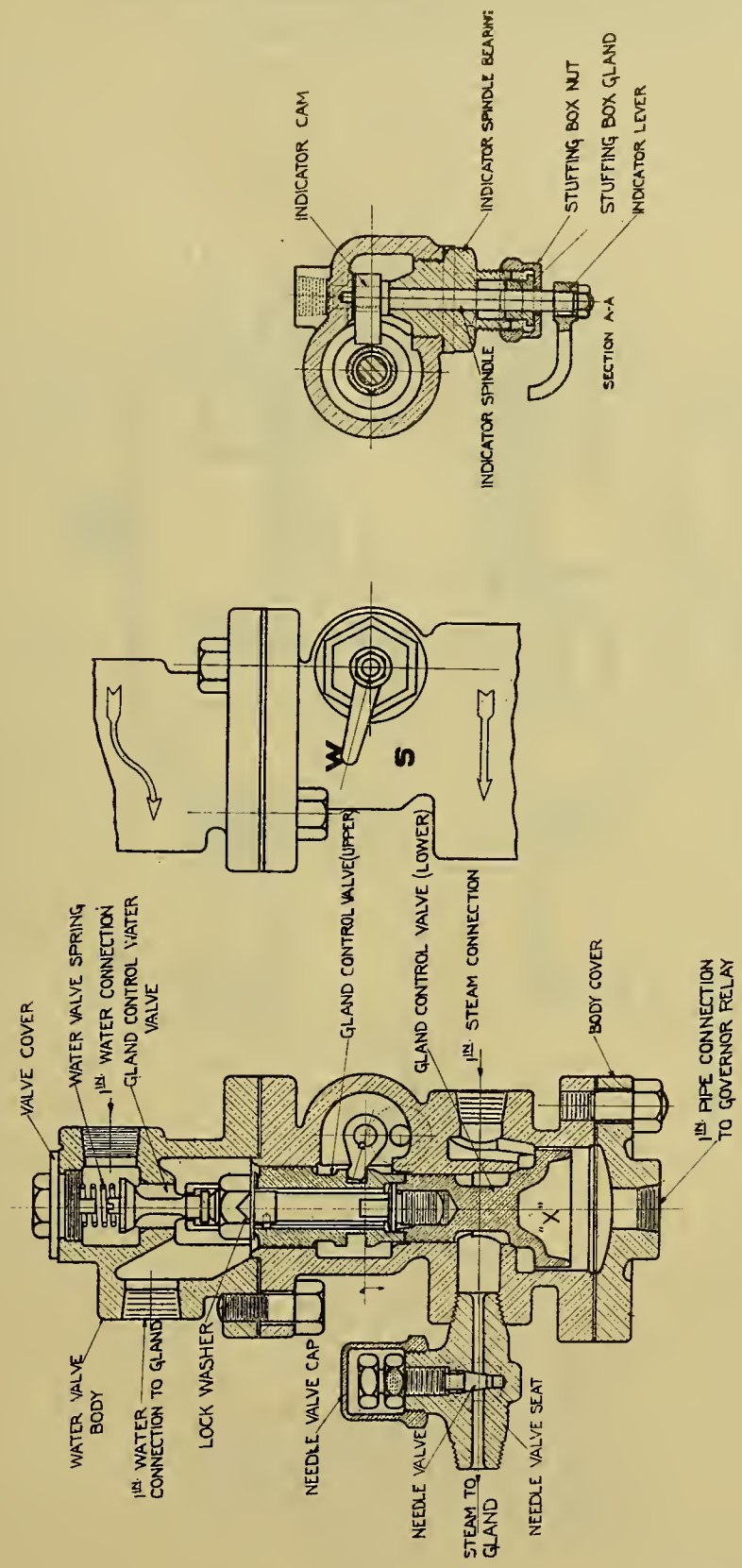

Fig. 33 - Gland Control Valve.

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To illustrate paper on "Progress in Turbine Ship Propulsion," by Francis Hodgkinson, Esq., Visitor.

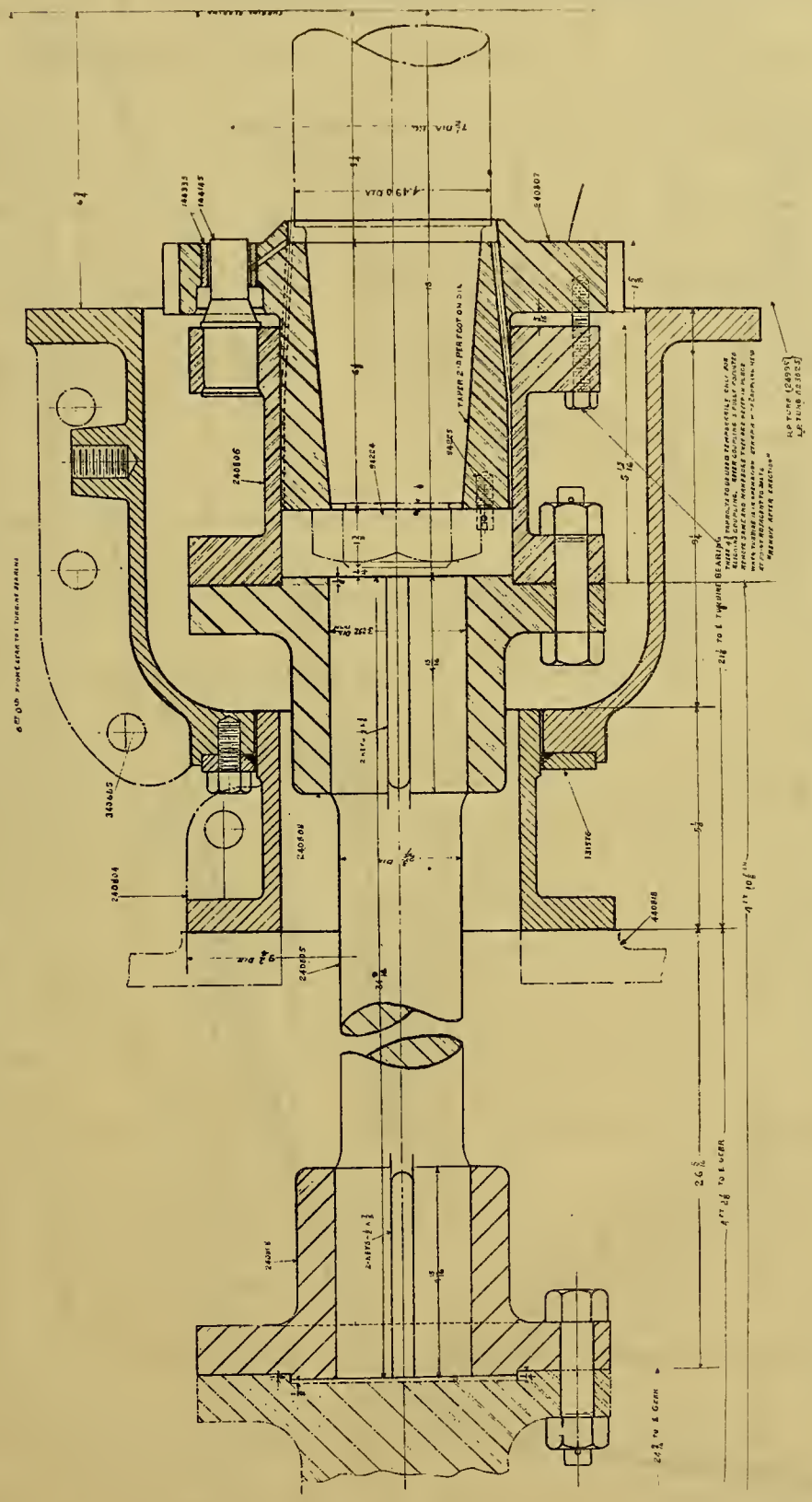
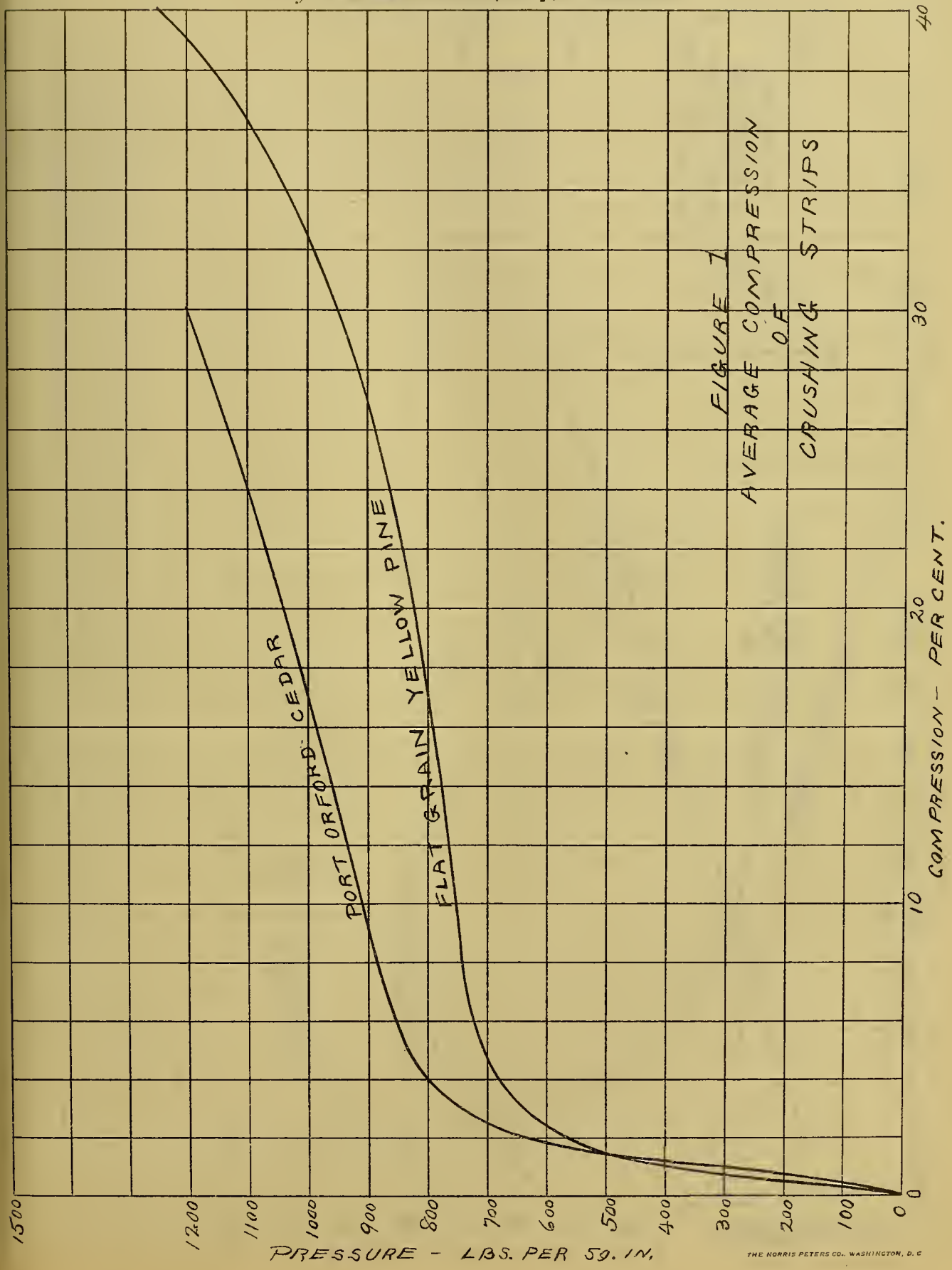


Fig. 34 - Flexible Shaft and Coupling.

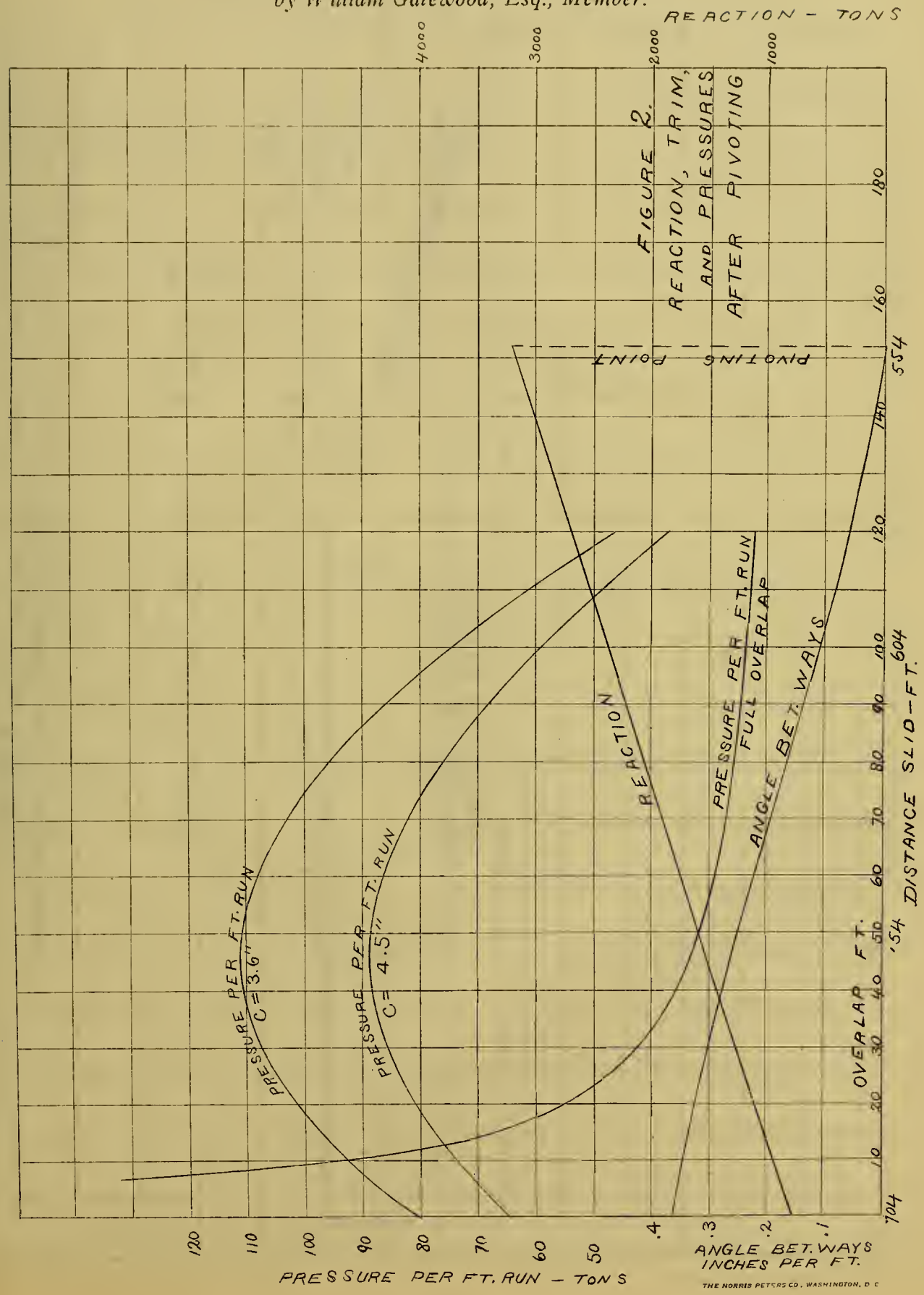
THE NORRIS PETERS CO., WASHINGTON D. C.

To illustrate paper on "Notes on Launching," by William Gatewood, Esq., Member.



THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Notes on Launching," by William Gatewood, Esq., Member.



To illustrate paper on "Notes on Launching," by William Gatewood, Esq., Member.

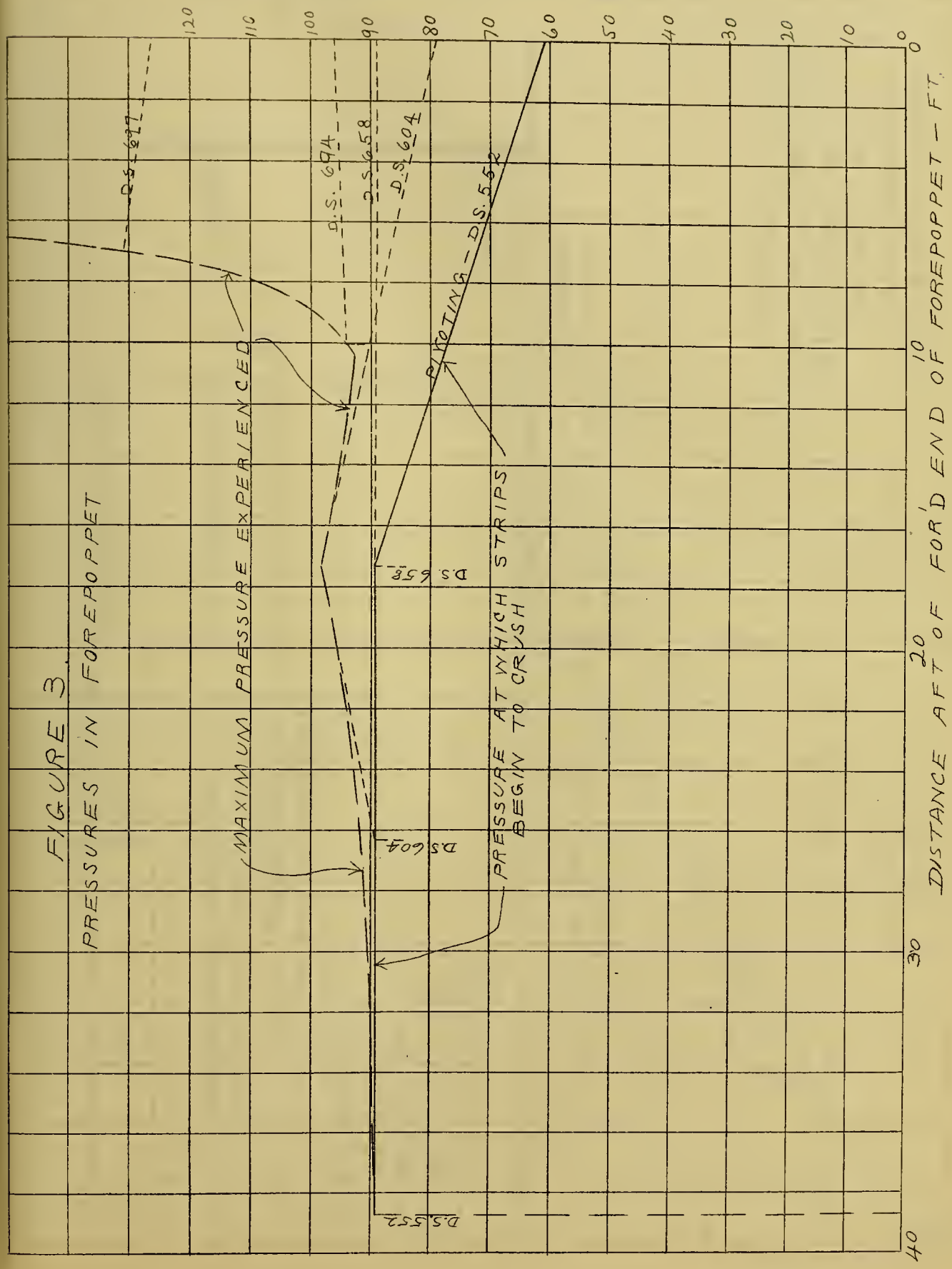


FIGURE 3.
PRESSURES IN FOREPOPPET

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Notes on Launching," by William Gatewood, Esq., Member.

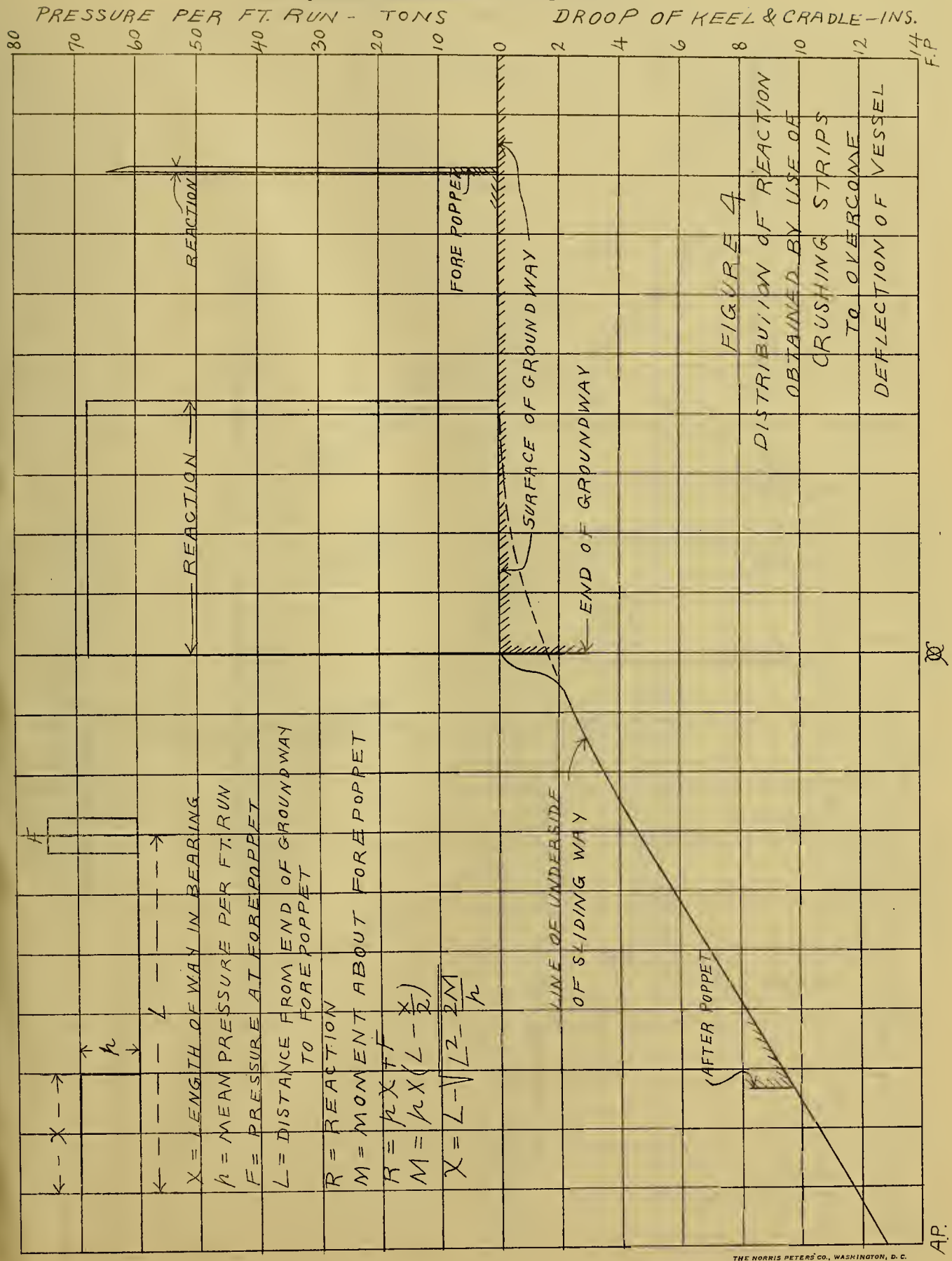
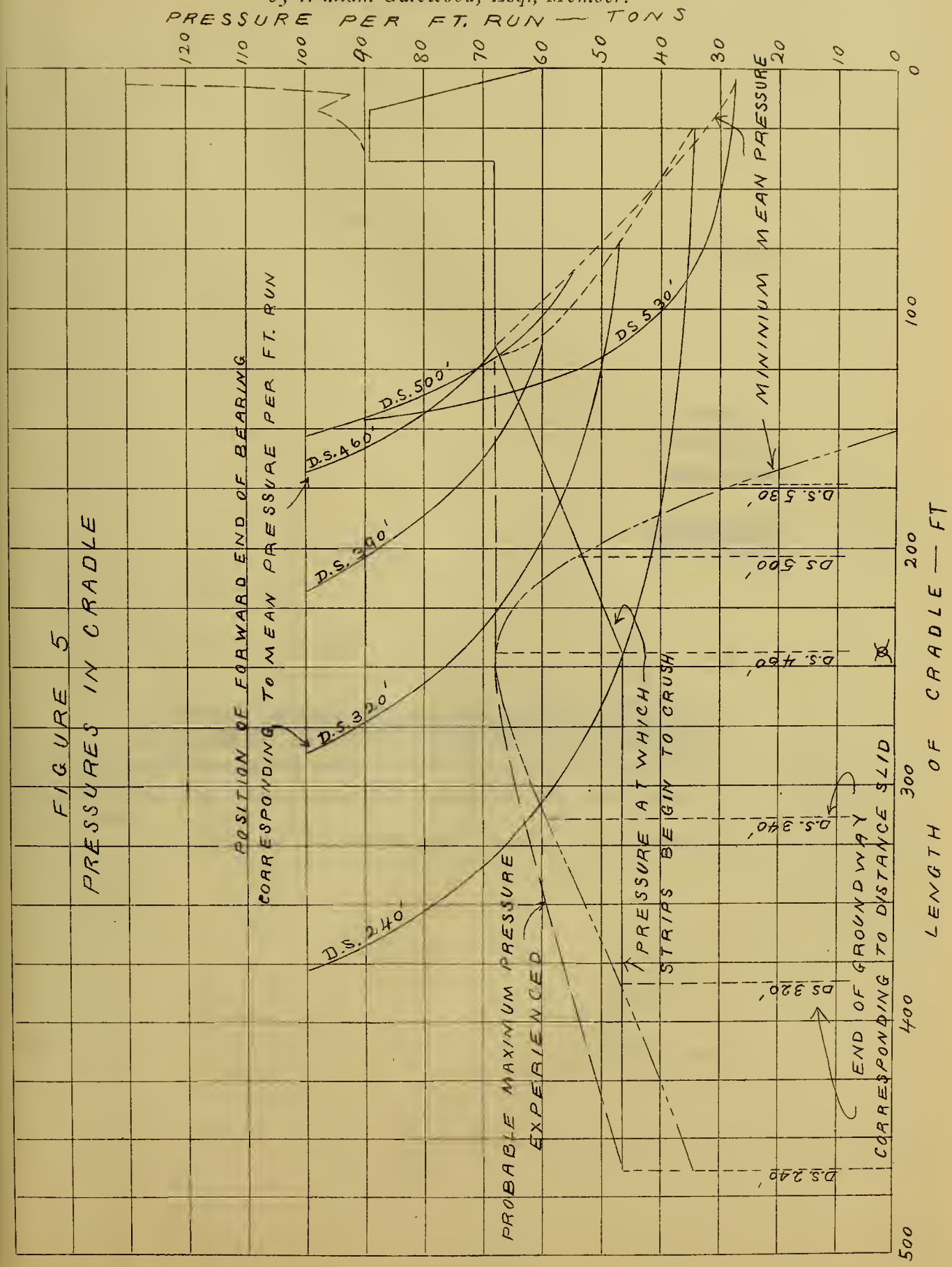


FIGURE 4
DISTRIBUTION OF REACTION OBTAINED BY USE OF CRUSHING STRIPS TO OVERCOME DEFLECTION OF VESSEL

THE NORRIS PETERS CO., WASHINGTON, D. C.

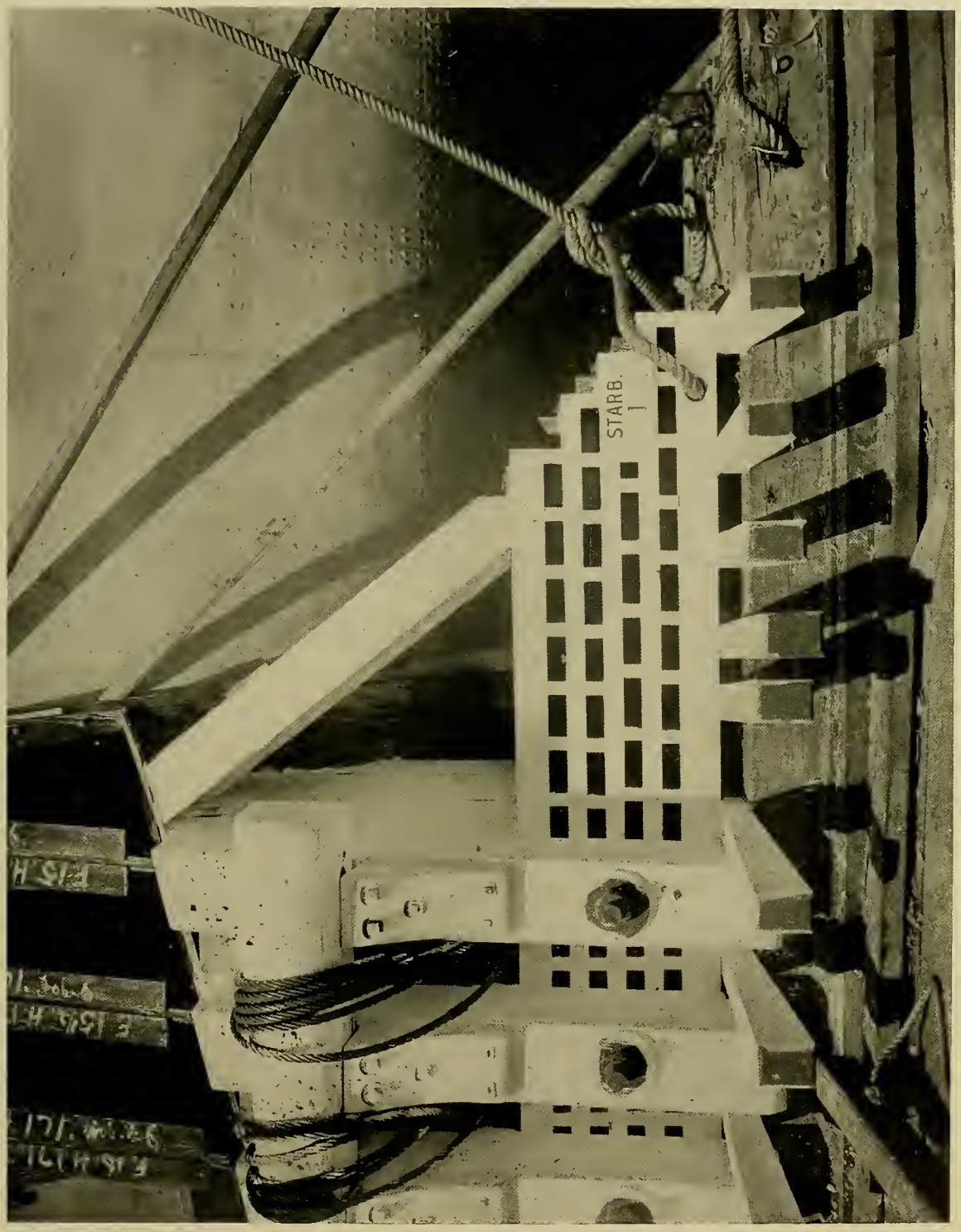
To illustrate paper on "Notes on Launching," by William Gatewood, Esq., Member.



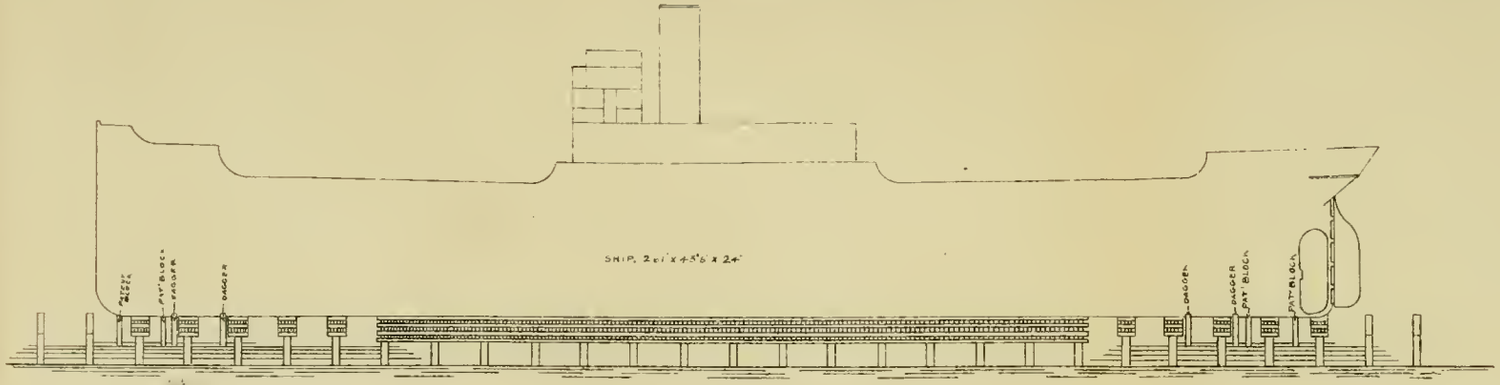
THE NORRIS PETERS CO., WASHINGTON, D. C

ARRANGEMENT
OF
CRUSHING STRIPS

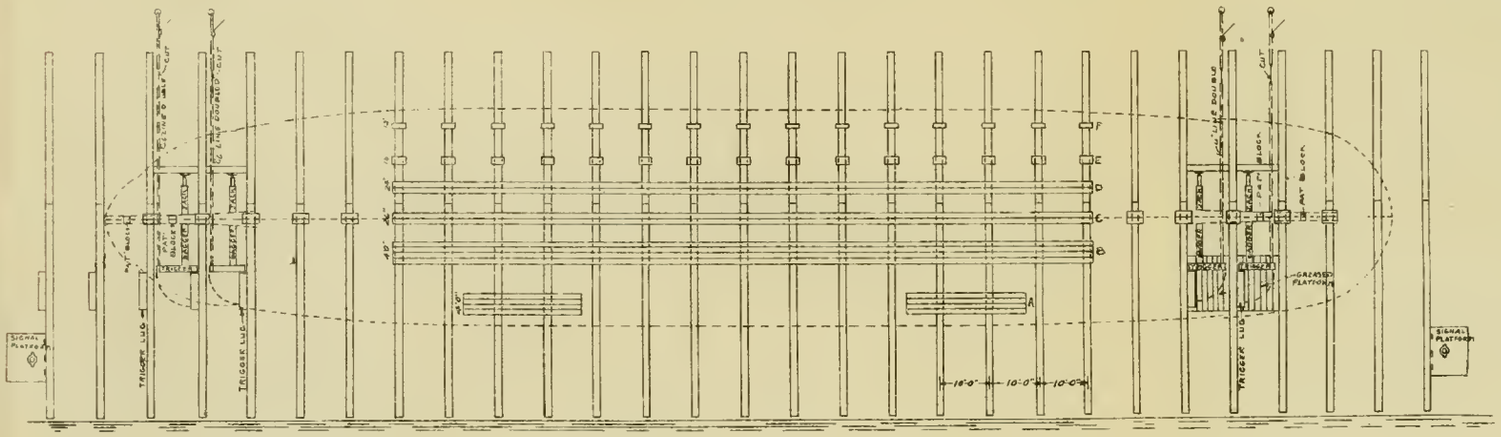
To illustrate paper on "Notes on Launching," by William Gatewood, Esq., Member.



To illustrate paper on "Side Launching of Ships on the Great Lakes," by Frank E. Kirby, Esq., Honorary Vice-President, and Edward Hopkins, Esq., Member.



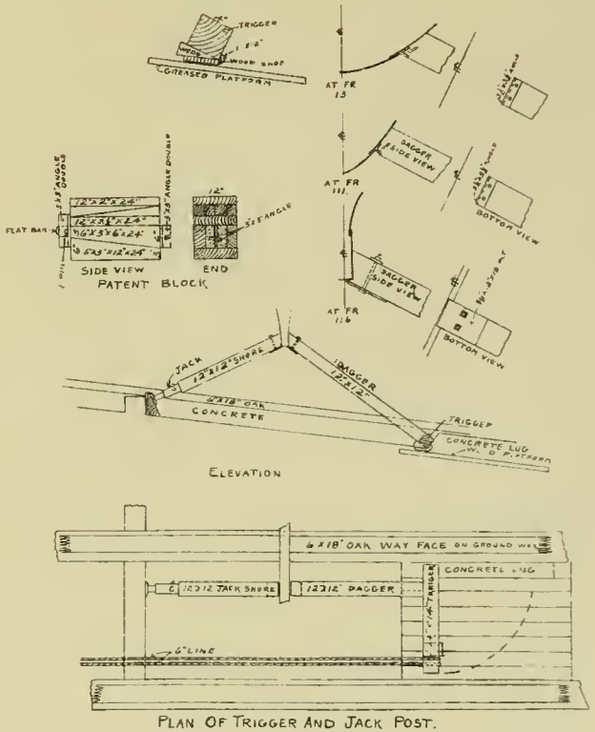
SIDE ELEVATION OF WAYS SHOWING CRADLE, TRIGGERS AND PATENT BLOCKS



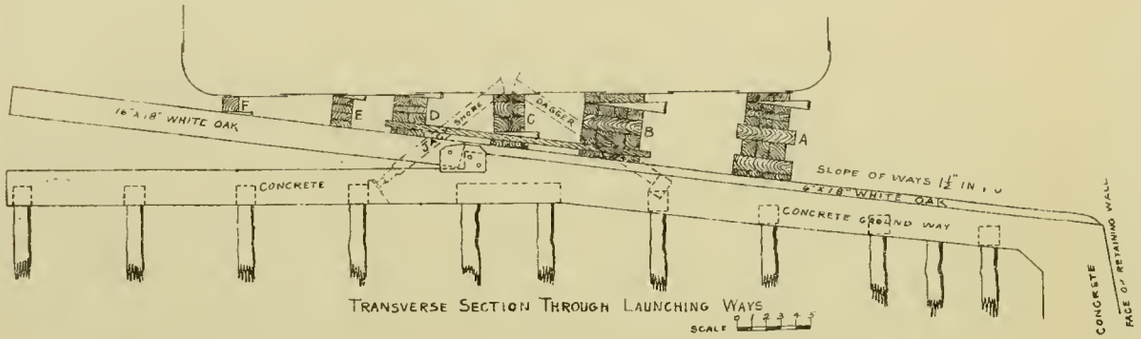
DRY DOCK

PLAN OF LAUNCHING WAYS

SCALE



PLAN OF TRIGGER AND JACK POST.

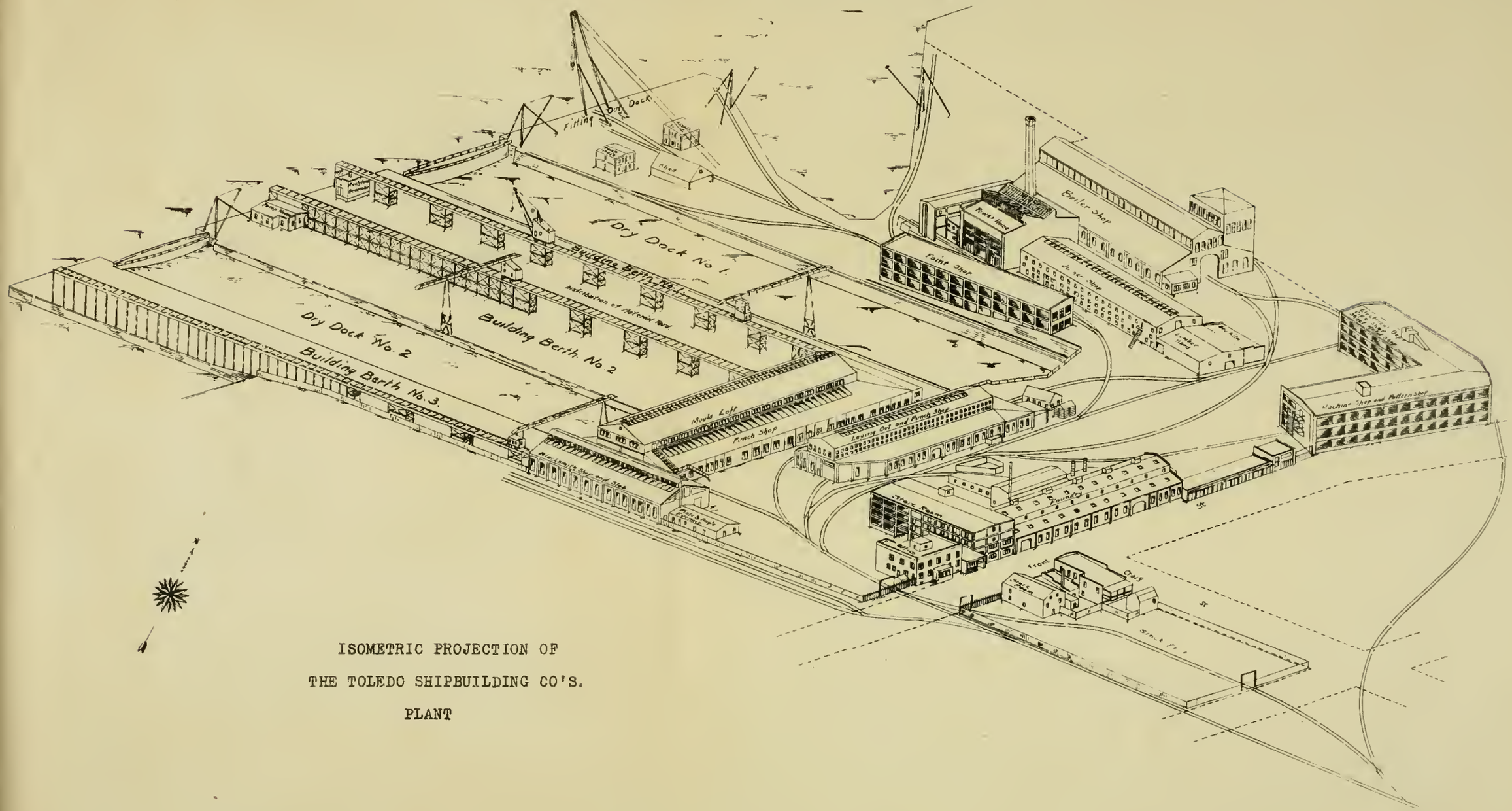


TRANSVERSE SECTION THROUGH LAUNCHING WAYS

SCALE

THE NORRIS PETERS CO., WASHINGTON

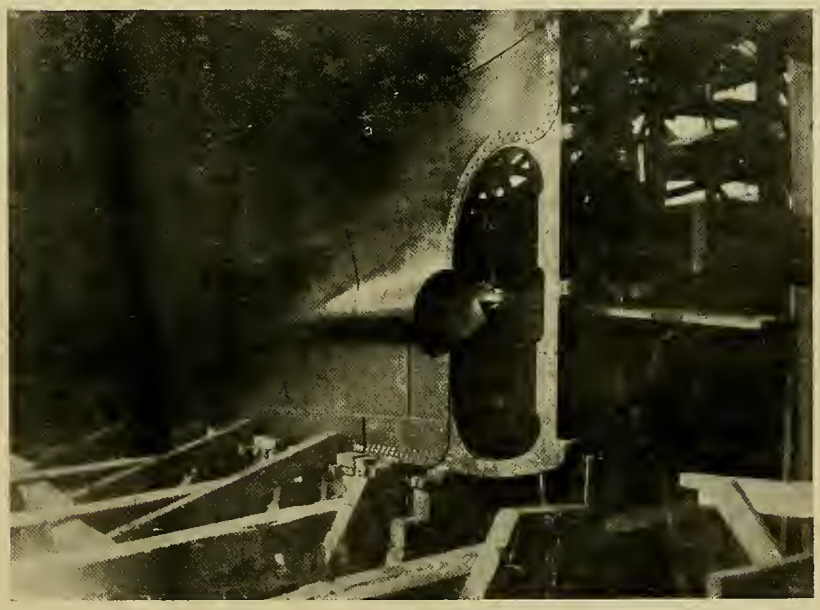
To illustrate paper on "Side Launching of Ships on the Great Lakes," by Frank E. Kirby, Esq., Honorary Vice-President, and Edward Hopkins, Esq., Member.



ISOMETRIC PROJECTION OF
THE TOLEDO SHIPBUILDING CO'S.
PLANT

To illustrate paper on "Side Launching of Ships on the Great Lakes," by Frank E. Kirby, Esq., Honorary Vice-President, and Edward Hopkins, Esq., Member.

DAGGERS AND TRIGGERS.



DAGGERS.

To illustrate paper on "Side Launching of Ships on the Great Lakes," by Frank E. Kirby, Esq., Honorary Vice-President, and Edward Hopkins, Esq., Member.

OVERBOARD.

To illustrate paper on "Side Launching of Ships on the Great Lakes," by Frank E. Kirby, Esq., Honorary Vice-President, and Edward Hopkins, Esq., Member.

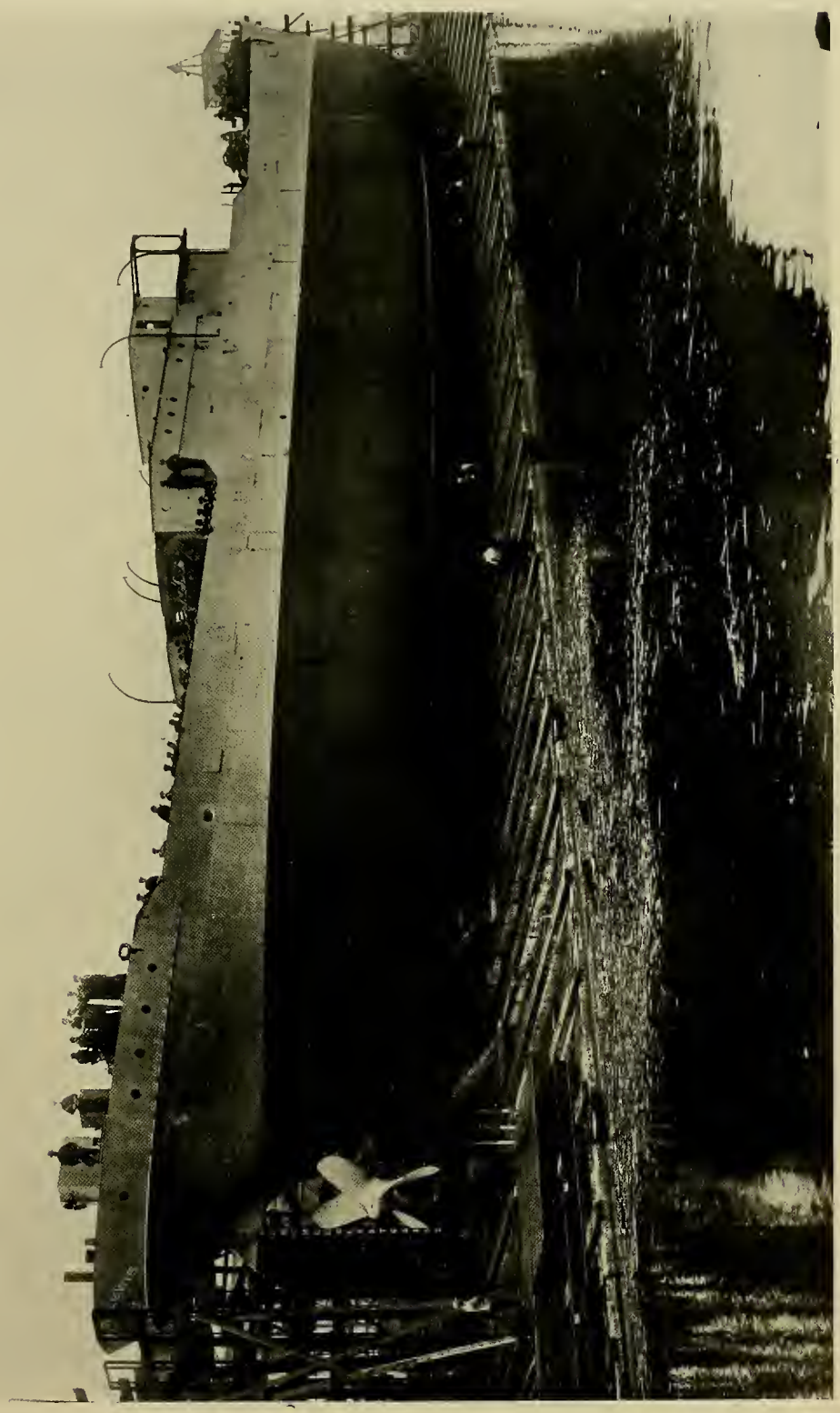
SHORES AND DAGGERS.

To illustrate paper on "Side Launching of Ships on the Great Lakes," by Frank E. Kirby, Esq., Honorary Vice-President, and Edward Hopkins, Esq., Member.

SEMAPHORE.

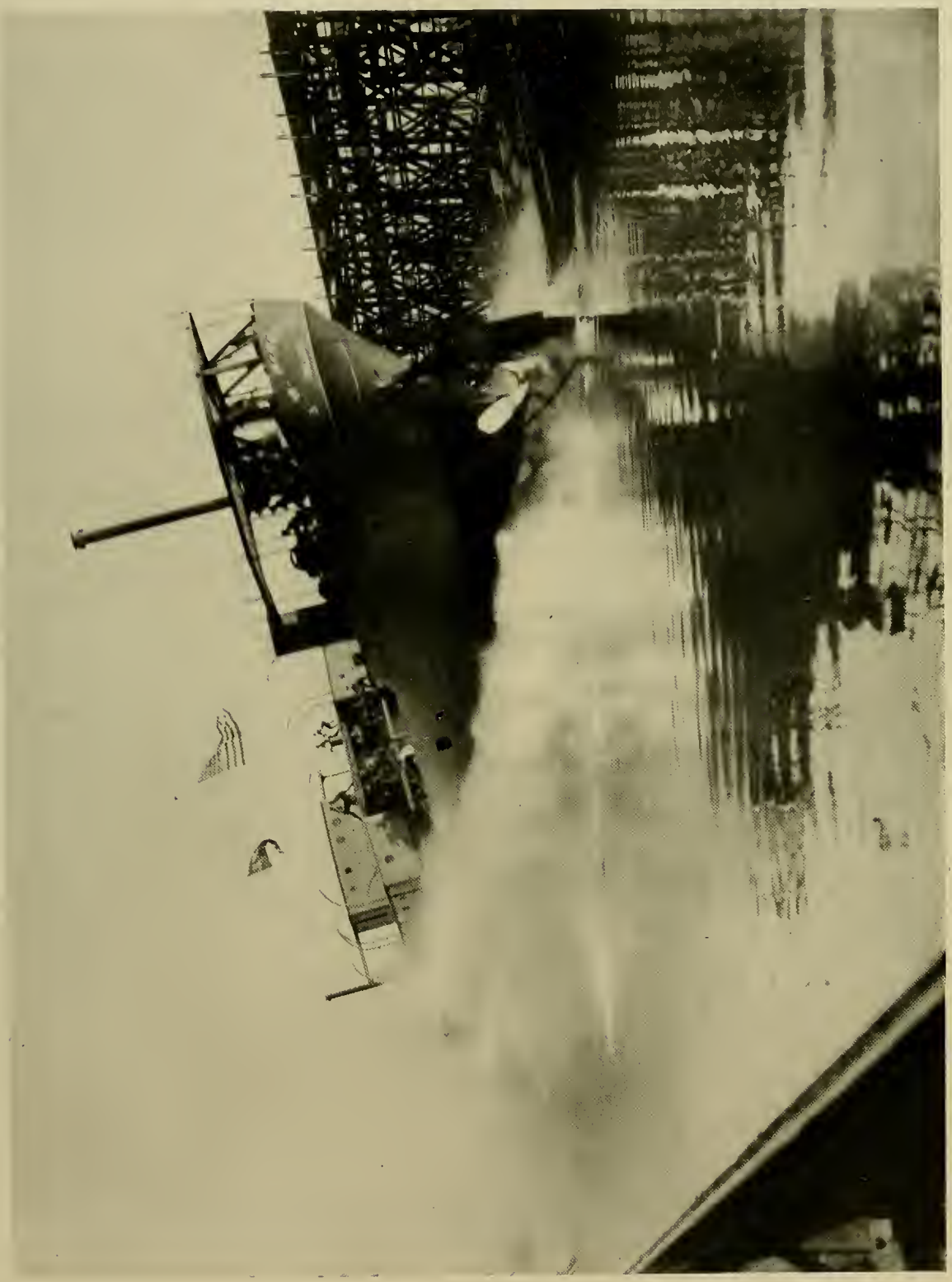
SHORES AND CRADLE.

To illustrate paper on "Side Launching of Ships on the Great Lakes," by Frank E. Kirby, Esq., Honorary Vice-President, and Edward Hopkins, Esq., Member.



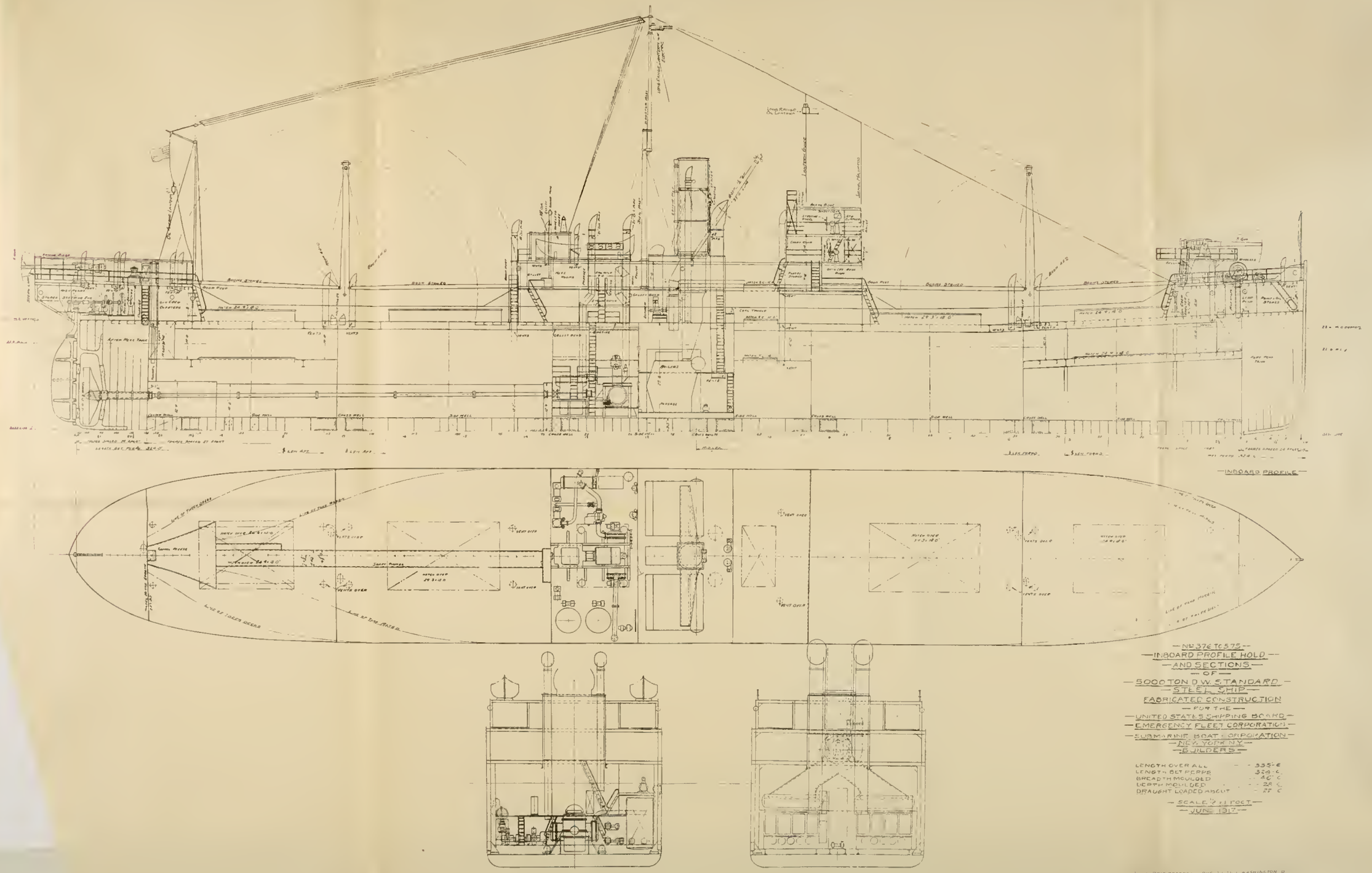
WEDGING UP.

To illustrate paper on "Side Launching of Ships on the Great Lakes," by Frank E. Kirby, Esq., Honorary Vice-President, and Edward Hopkins, Esq., Member.



OVERBOARD.

To illustrate paper on "Structural Steel Standardized Cargo Vessels," by Henry R. Sutphen, Esq., Member.



To illustrate paper on "Structural Steel Standardized Cargo Vessels," by Henry R. Sutphen, Esq., Member.

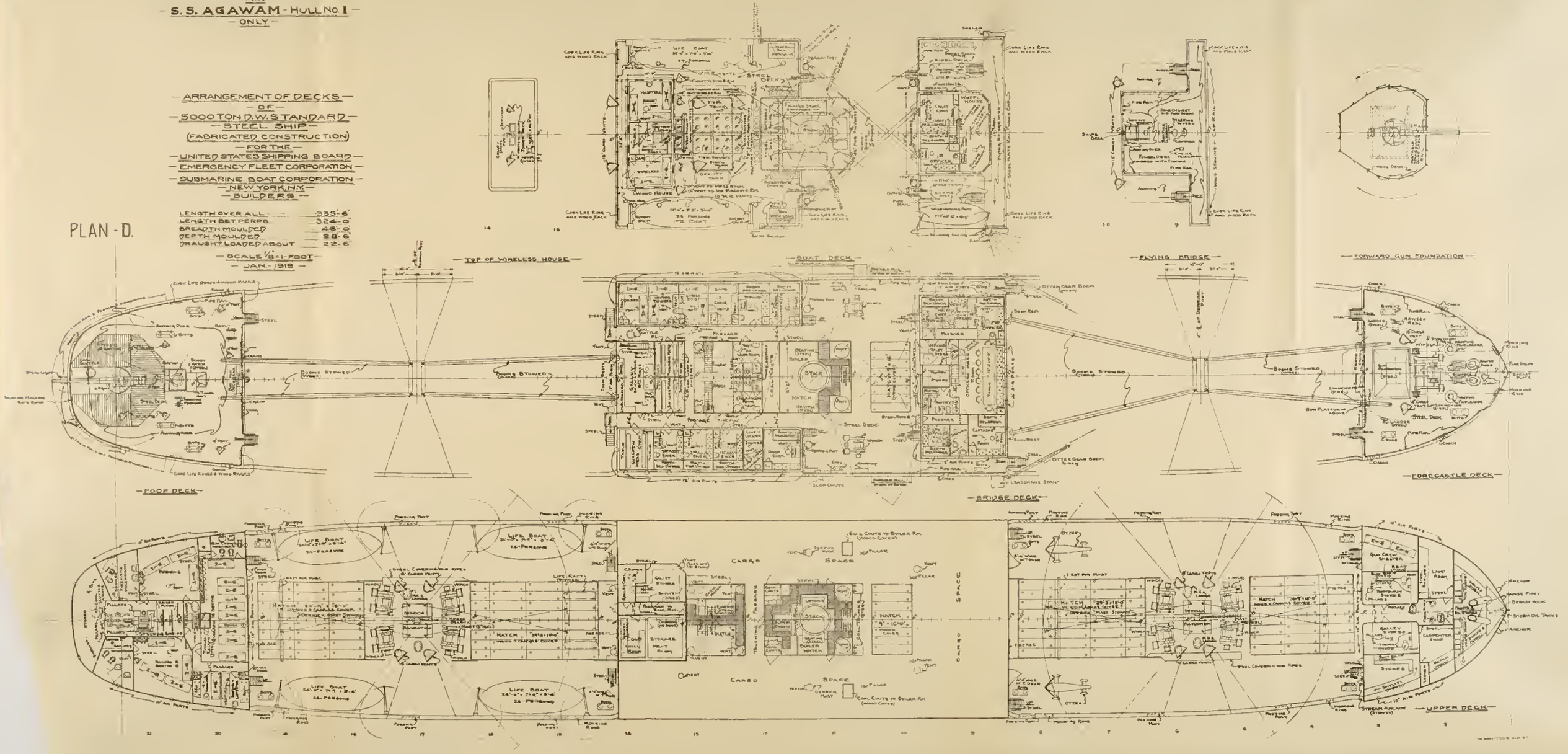
— THIS ARRANGEMENT IS —
— FOR —
— S. S. AGAWAM - HULL NO. 1 —
— ONLY —

— ARRANGEMENT OF DECKS —
— OF —
— 5000 TON D.W. STANDARD —
— STEEL SHIP —
(FABRICATED CONSTRUCTION)
— FOR THE —
— UNITED STATES SHIPPING BOARD —
— EMERGENCY FLEET CORPORATION —
— SUBMARINE BOAT CORPORATION —
— NEW YORK, N.Y. —
— BUILDERS —

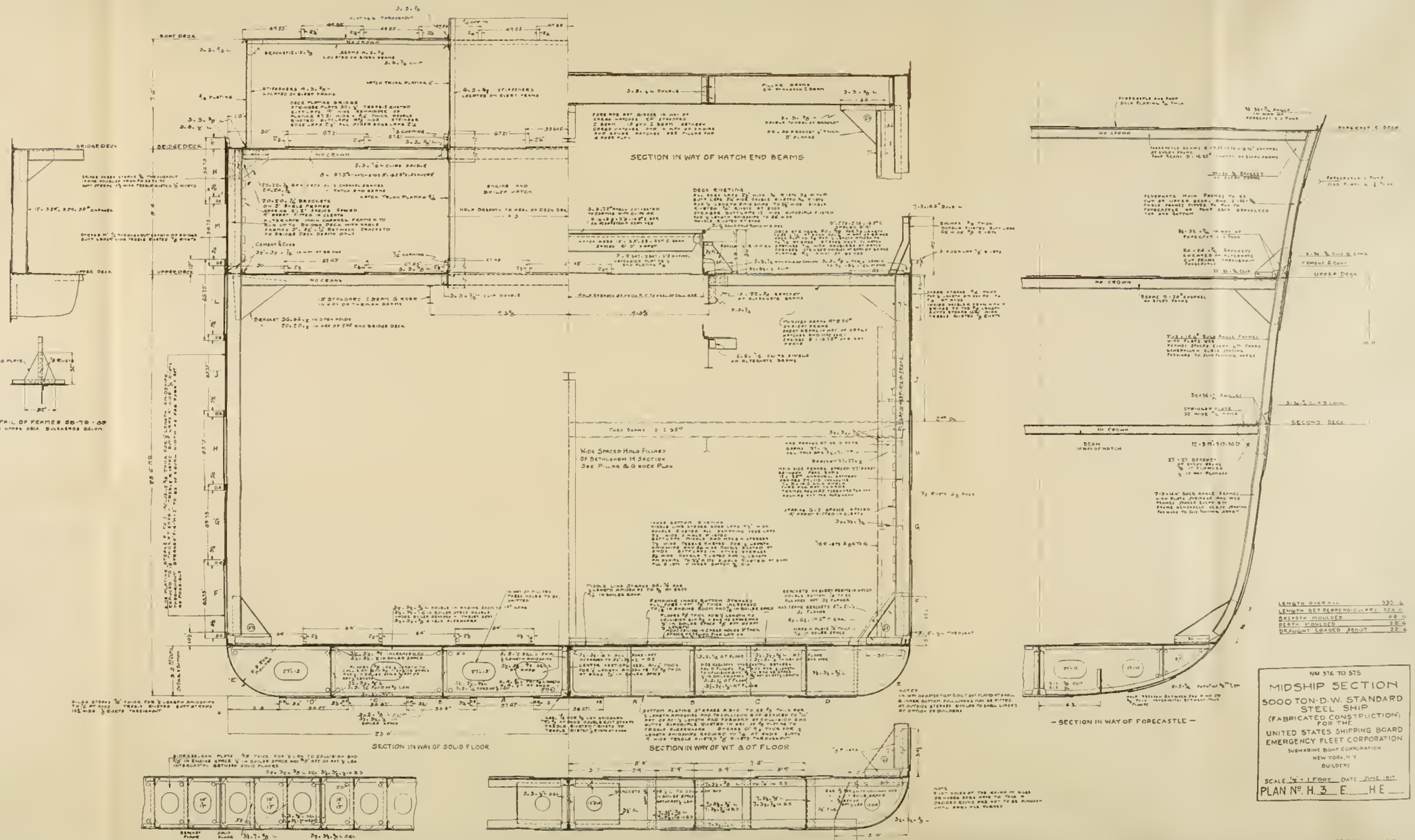
LENGTH OVER ALL	335'-6"
LENGTH BET. PERPS.	324'-0"
BREADTH MOULDED	46'-0"
DEPTH MOULDED	28'-6"
DRAUGHT LOADED ABOUT	22'-6"

— SCALE 1/8" = 1-FOOT —
— JAN. - 1919 —

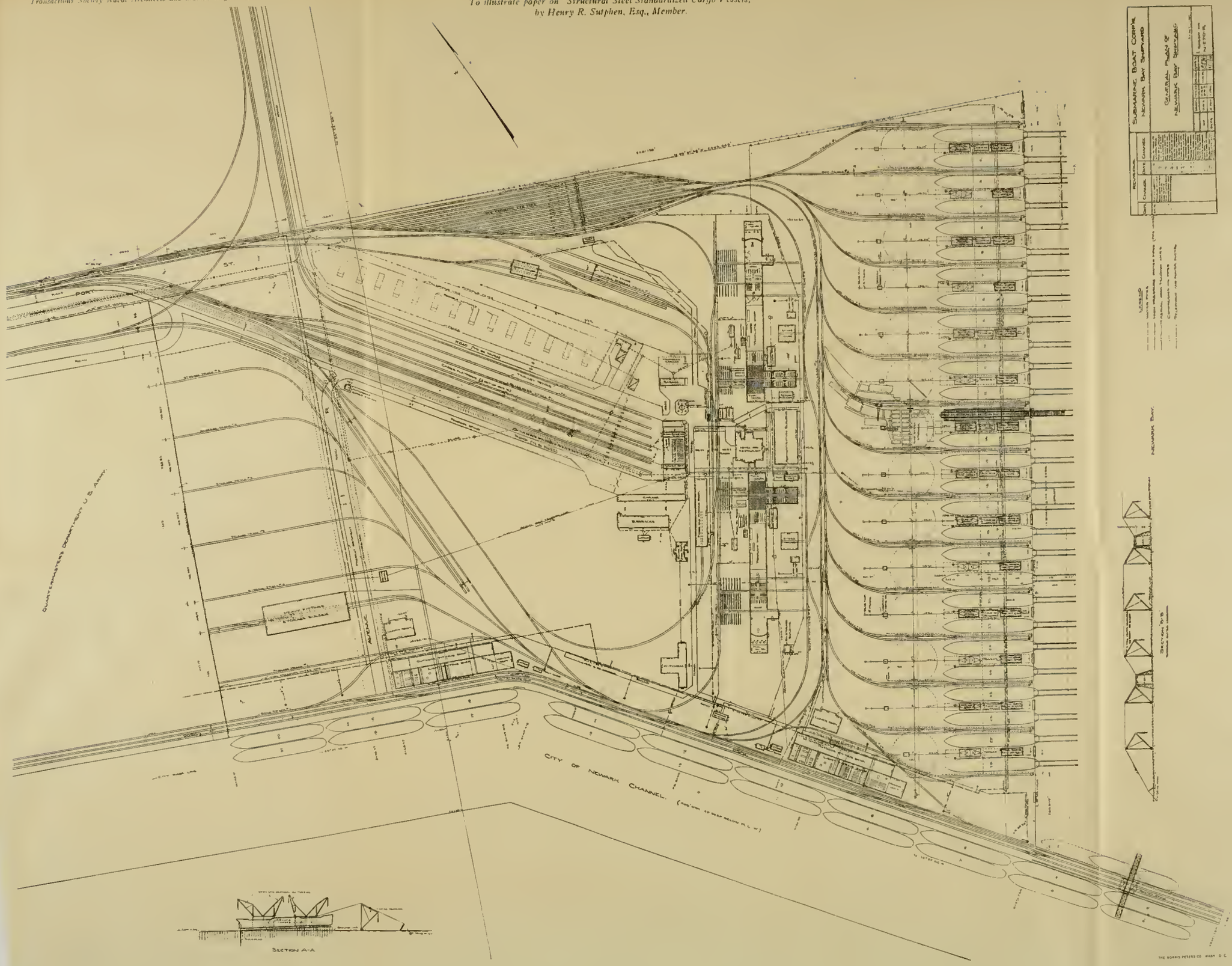
PLAN - D.



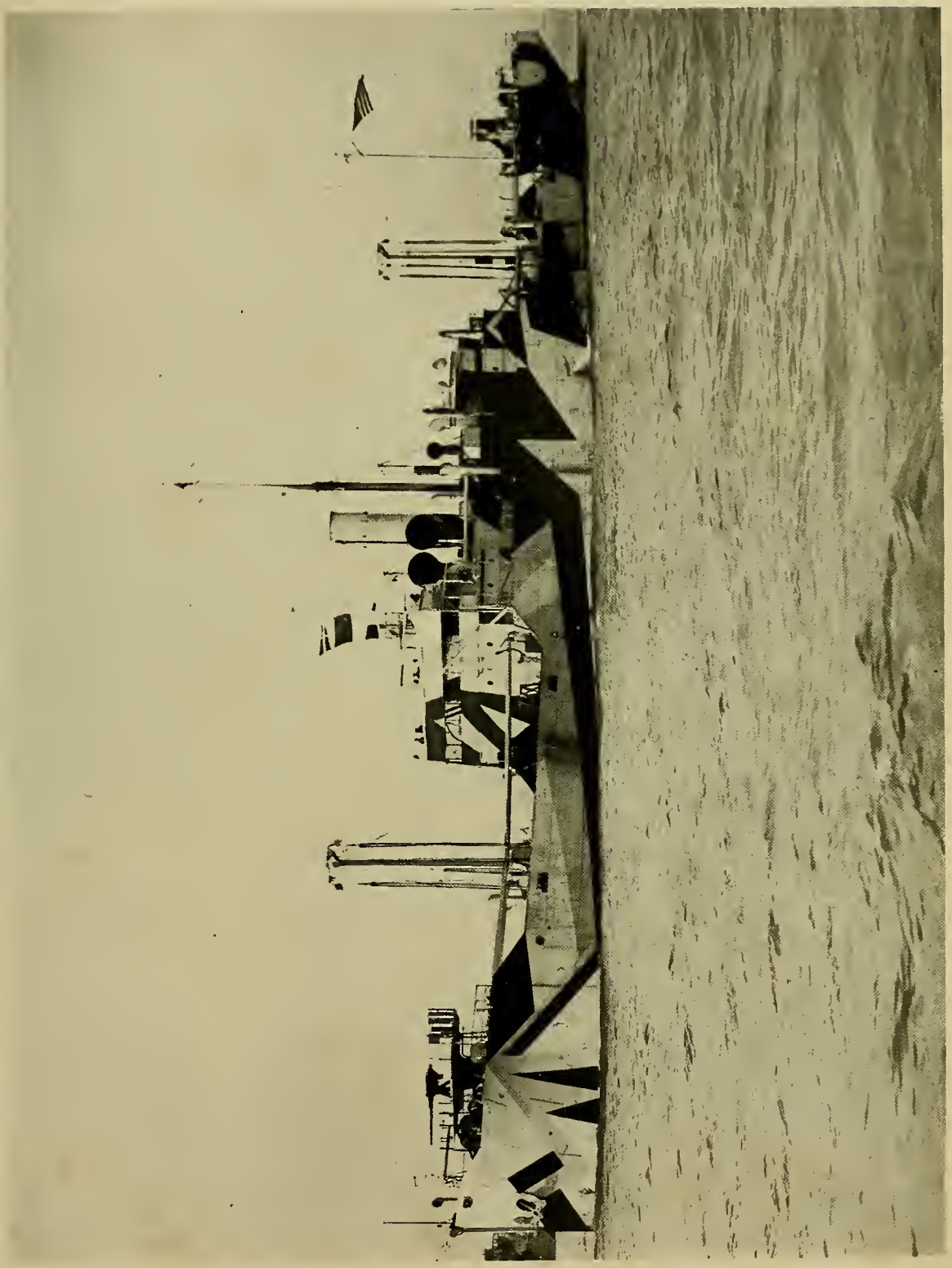
To illustrate paper on "Structural Steel Standardized Cargo Vessels," by Henry R. Sutphen, Esq., Member.



To illustrate paper on "Structural Steel Standardized Cargo Vessels," by Henry R. Sutphen, Esq., Member.

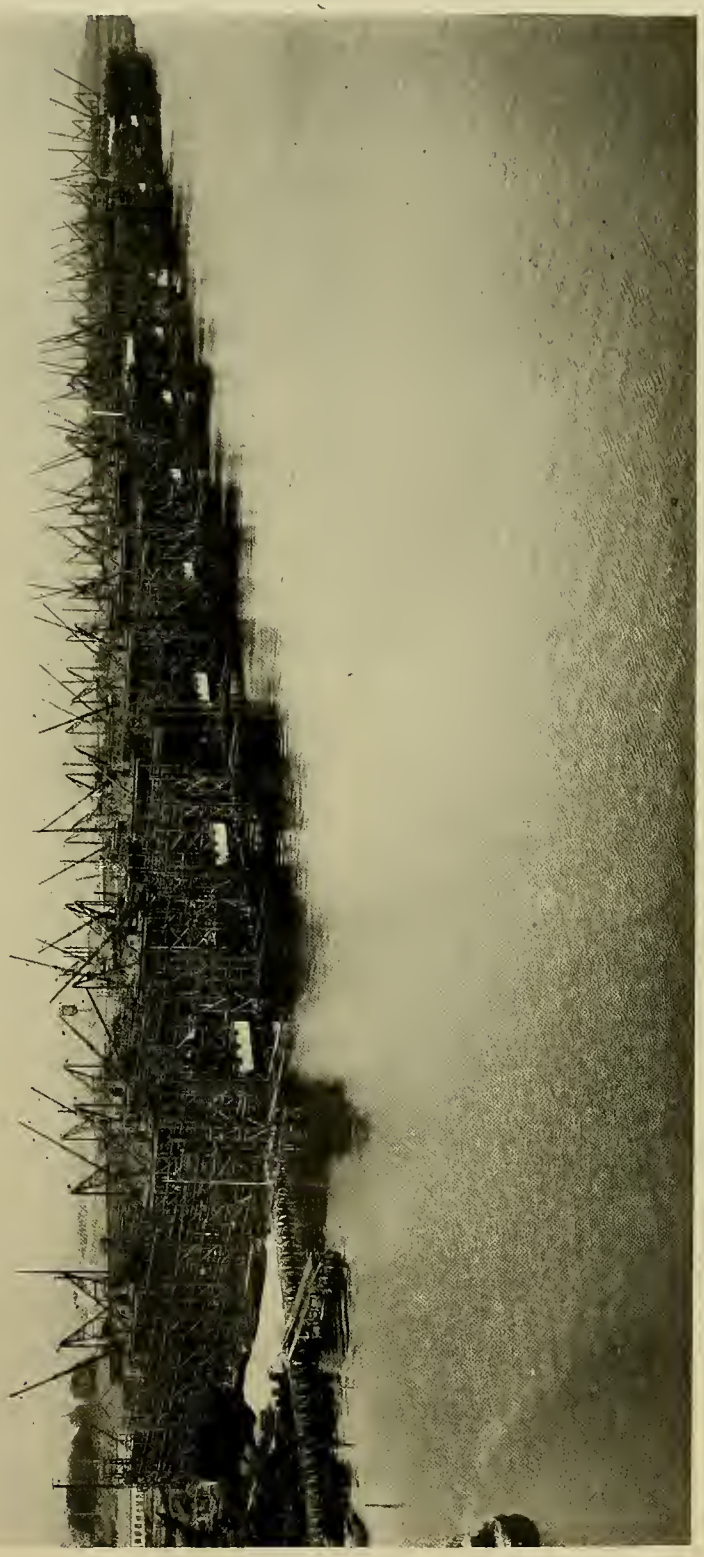


To illustrate paper on "Structural Steel Standardized Cargo Vessels," by Henry R. Sutphen, Esq., Member.



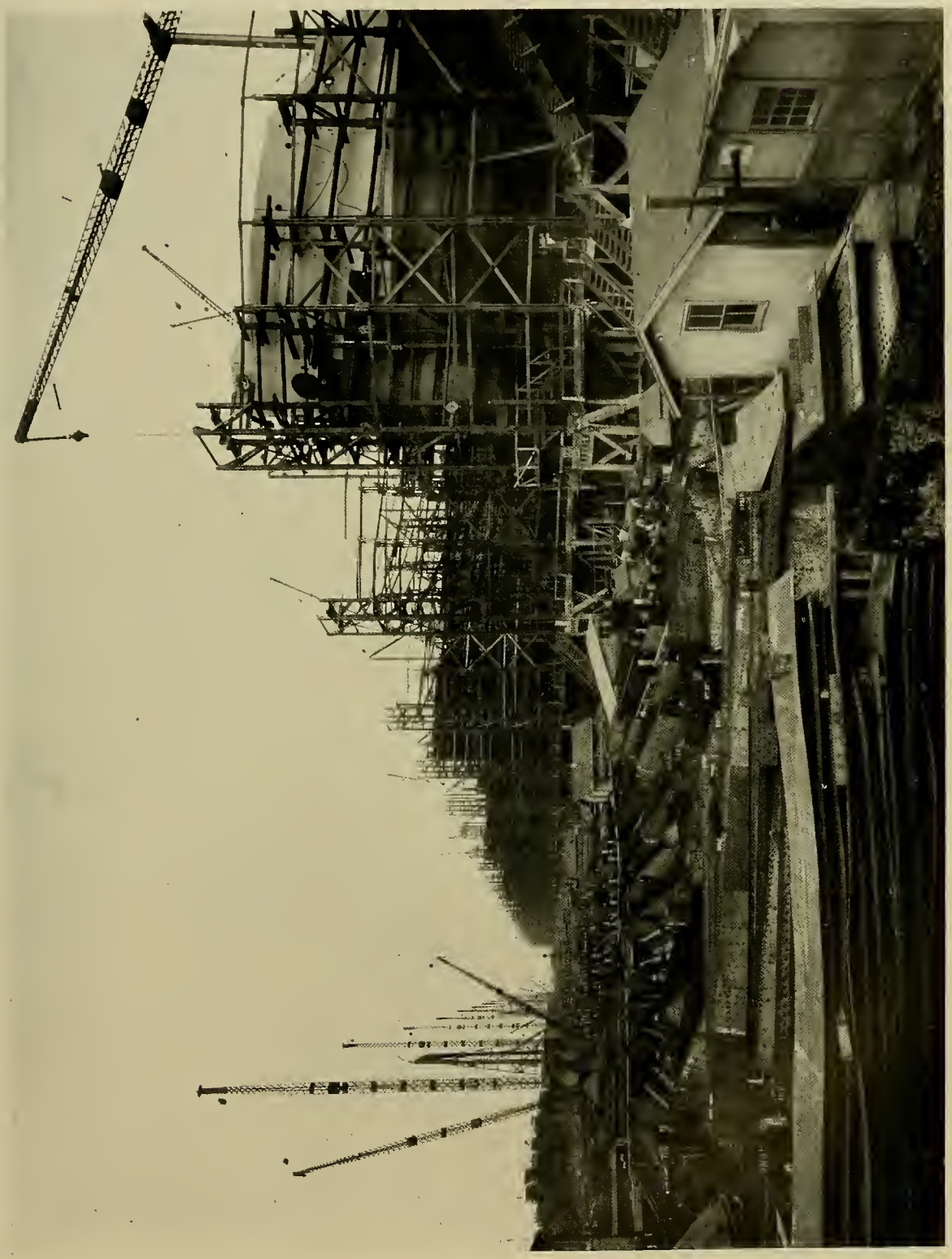
S. S. Agawam. First Structural Steel Ship. Type of Vessel Constructed at Newark Bay Shipyard.

To illustrate paper on "Structural Steel Standardized Cargo Vessels," by Henry R. Sutphen, Esq., Member.



Off-Shore View of Building Ways.

To illustrate paper on "Structural Steel Standardized Cargo Vessels," by Henry R. Sutphen, Esq., Member.



View of Ways, Showing Part of Material Yard.

To illustrate paper on "Structural Steel Standardized Cargo Vessels," by Henry R. Sutphen, Esq., Member.

View of Wet Basin.

To illustrate paper on "Structural Steel Standardized Cargo Vessels," by Henry R. Sutphen, Esq., Member.

SHIPS BEING FITTED OUT AT WET BASIN.

To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.

Y. 1.

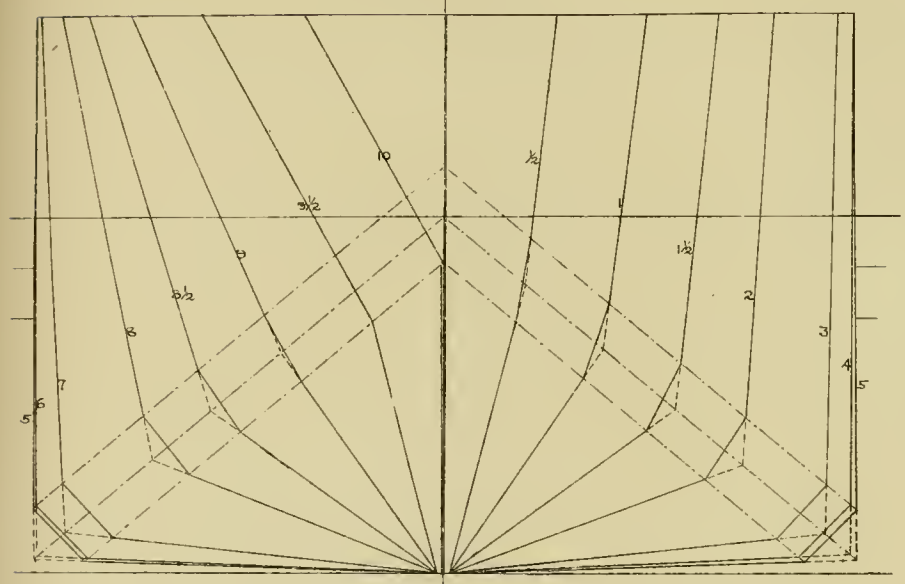


Fig. 1.

Y. 2.

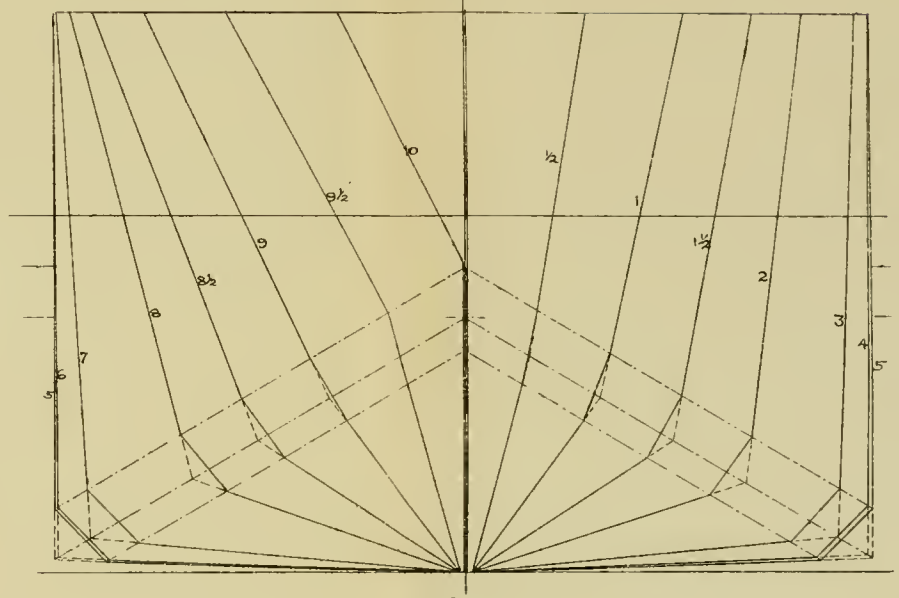


Fig. 2

Y. C.

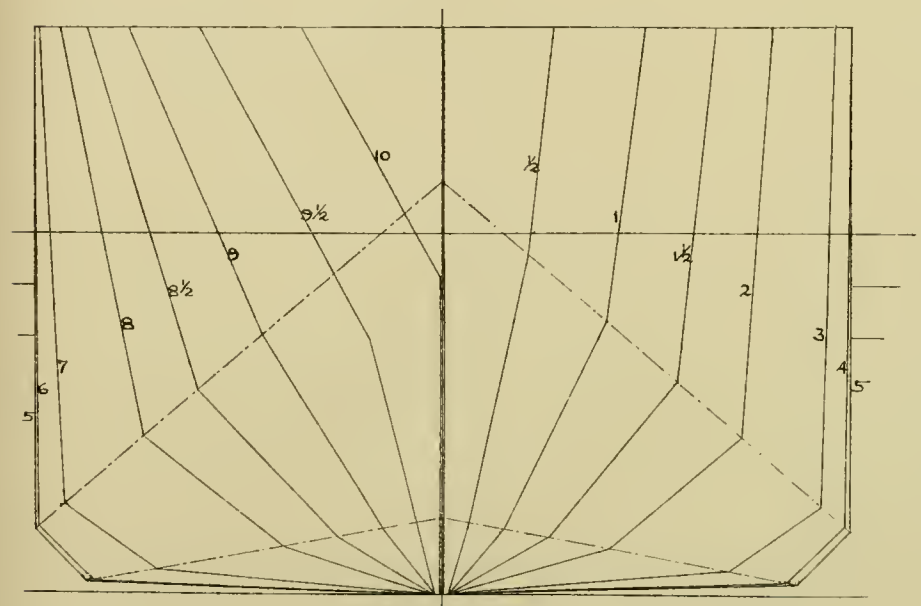


Fig. 1a.

Y. 3.

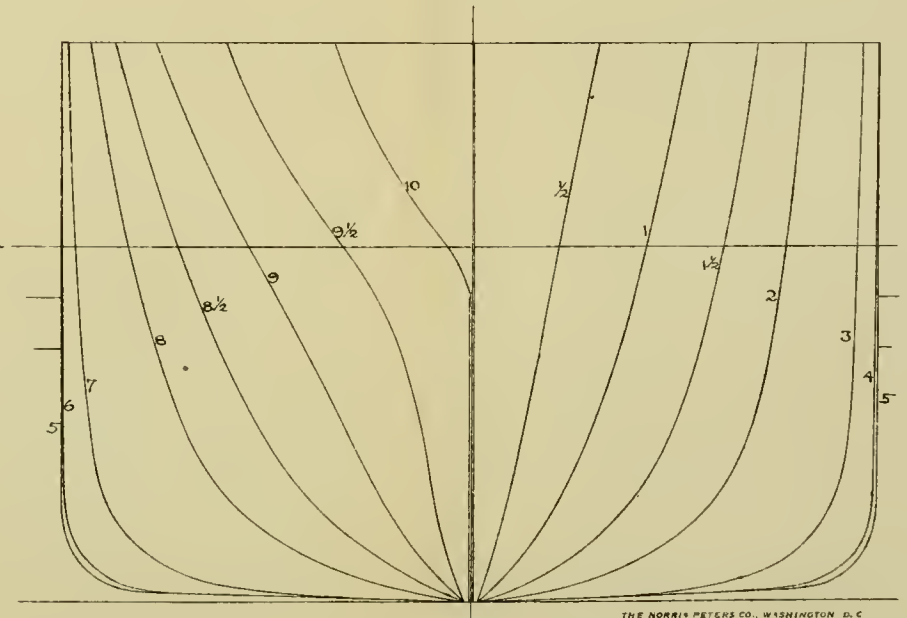
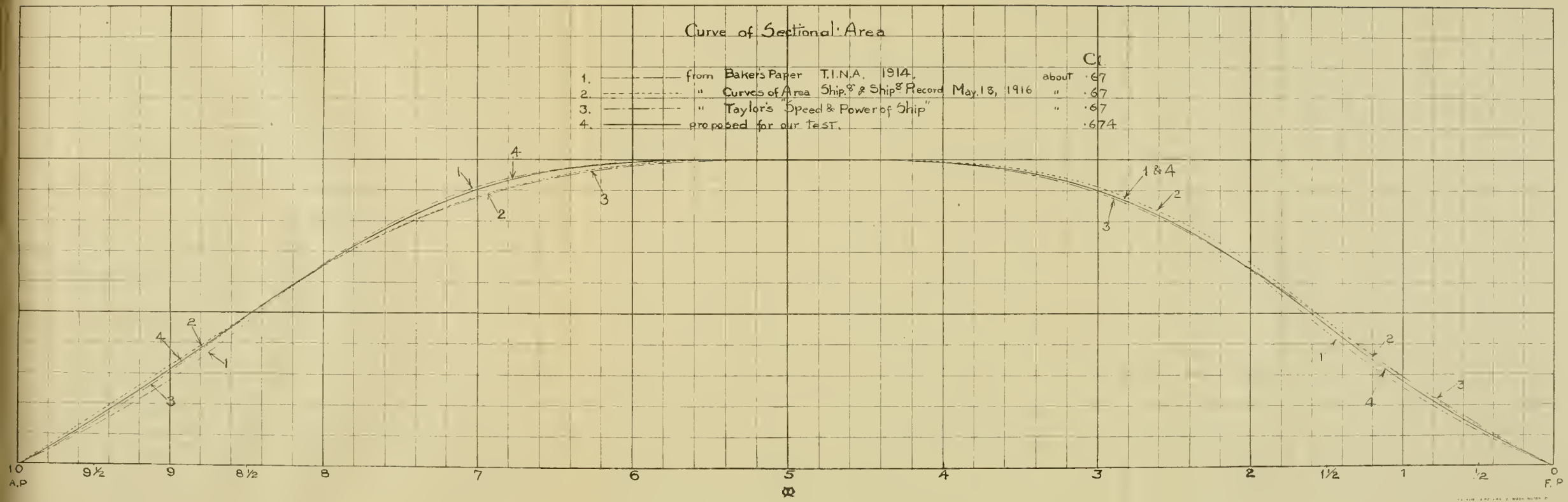


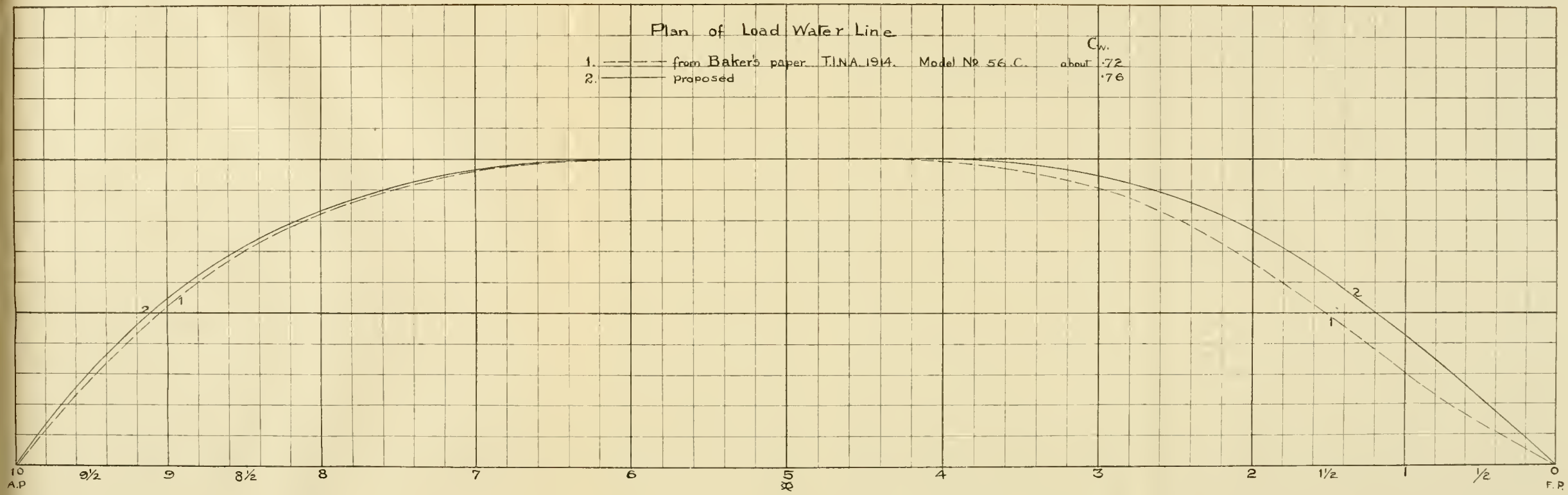
Fig. 3.

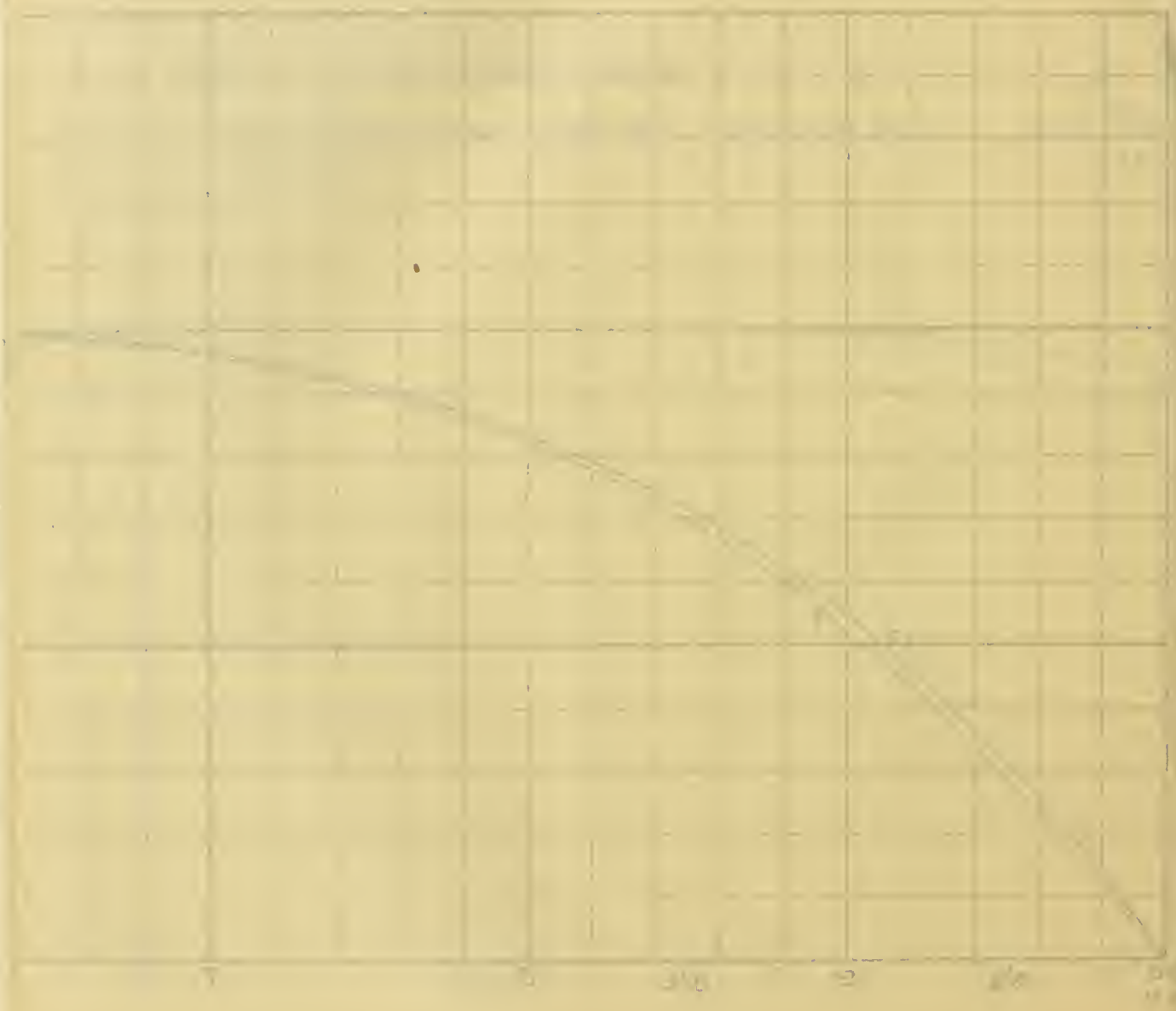
THE NORRIS PETERS CO., WASHINGTON D.C.

To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.



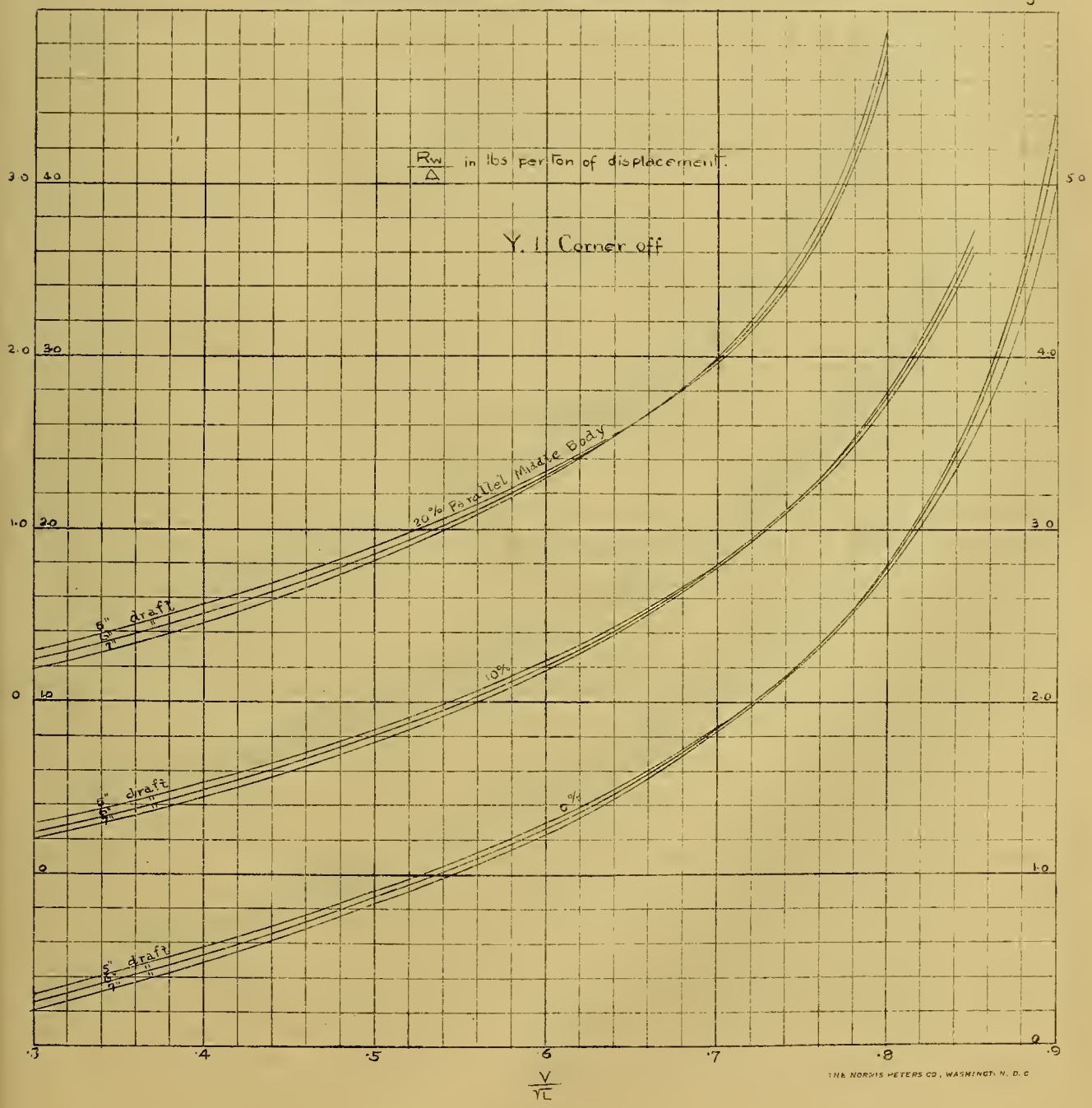
To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.





To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.

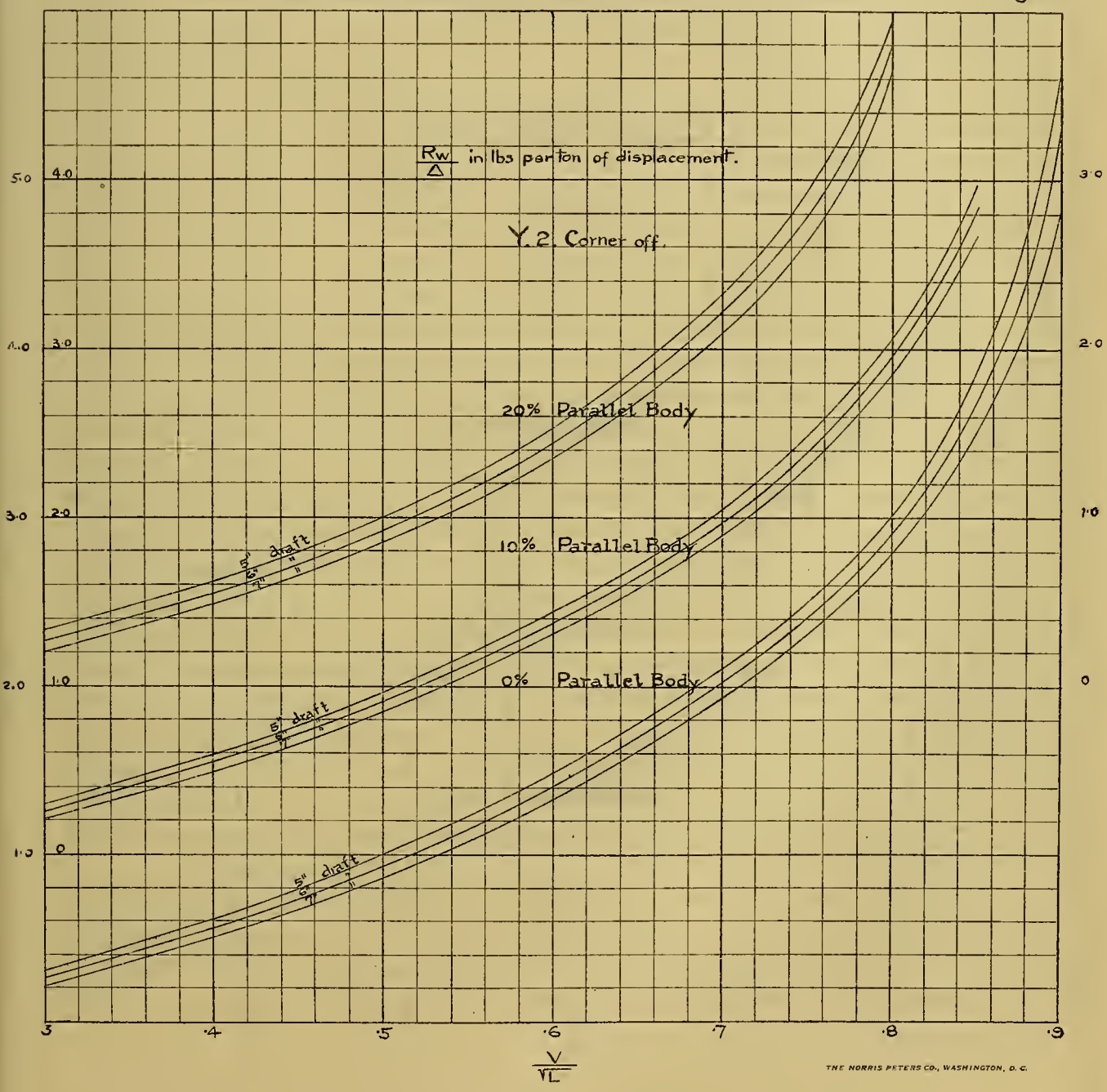
Fig 6.



THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.

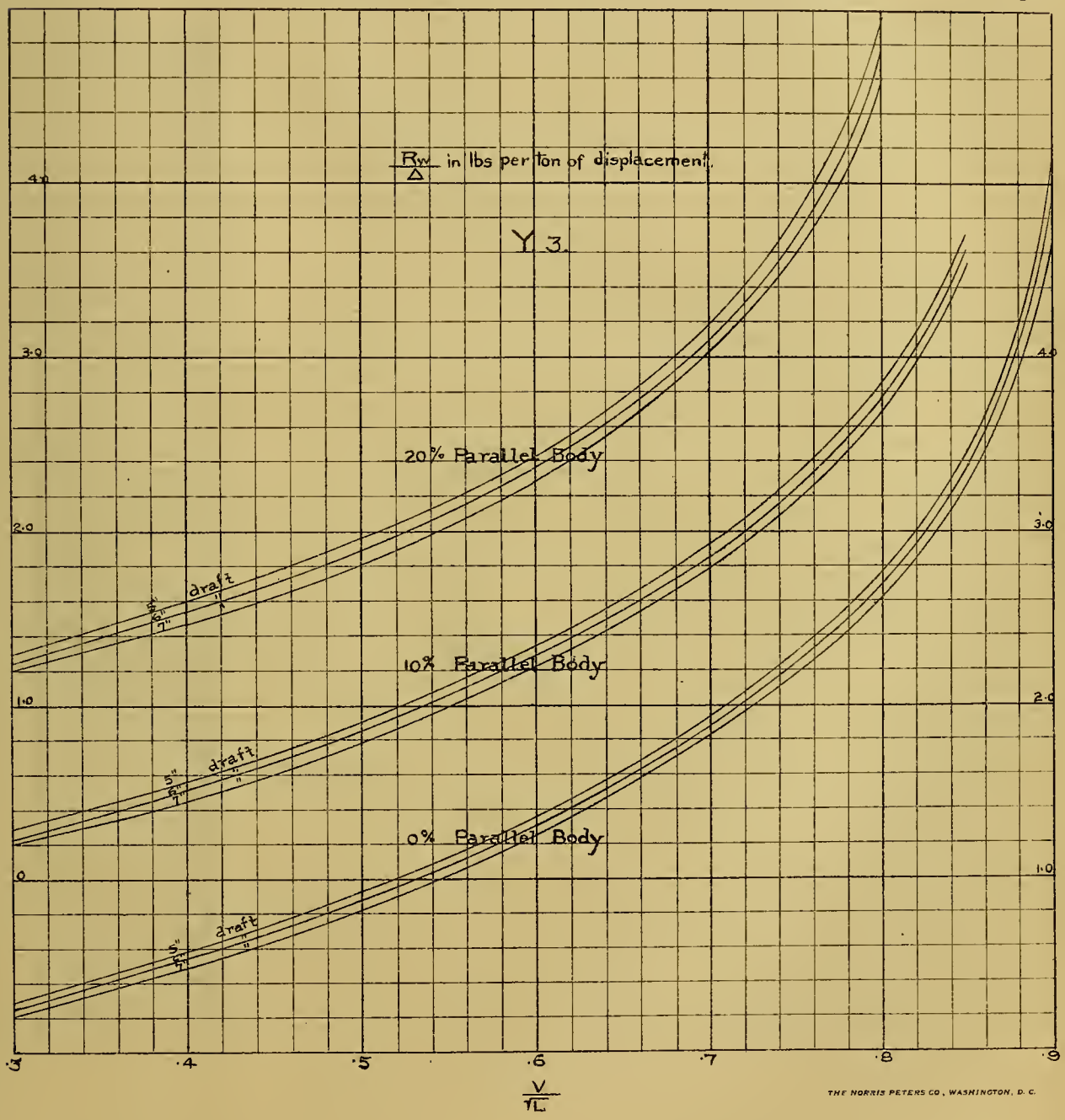
Fig 7.



THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.

Fig. 8.



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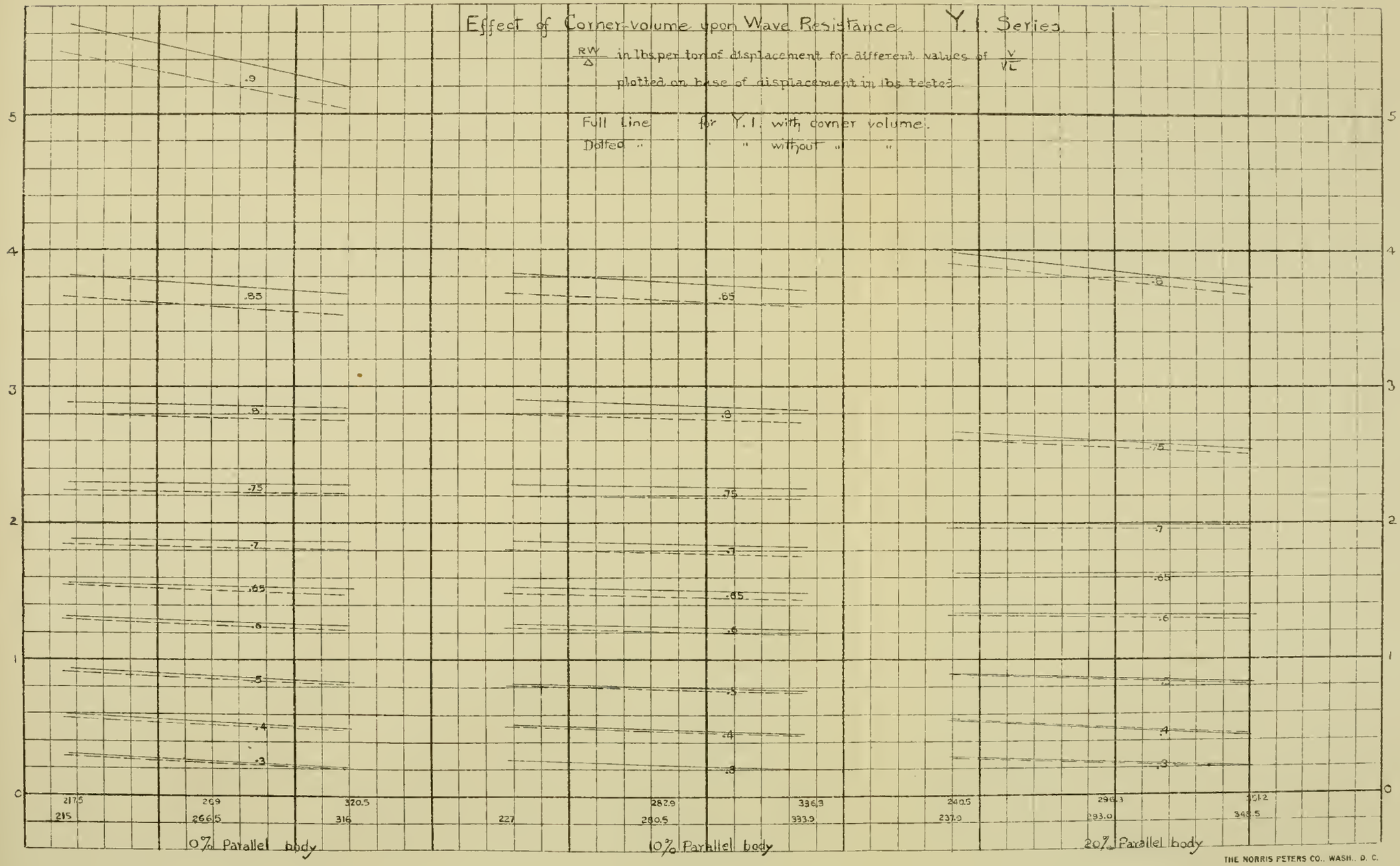
To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.

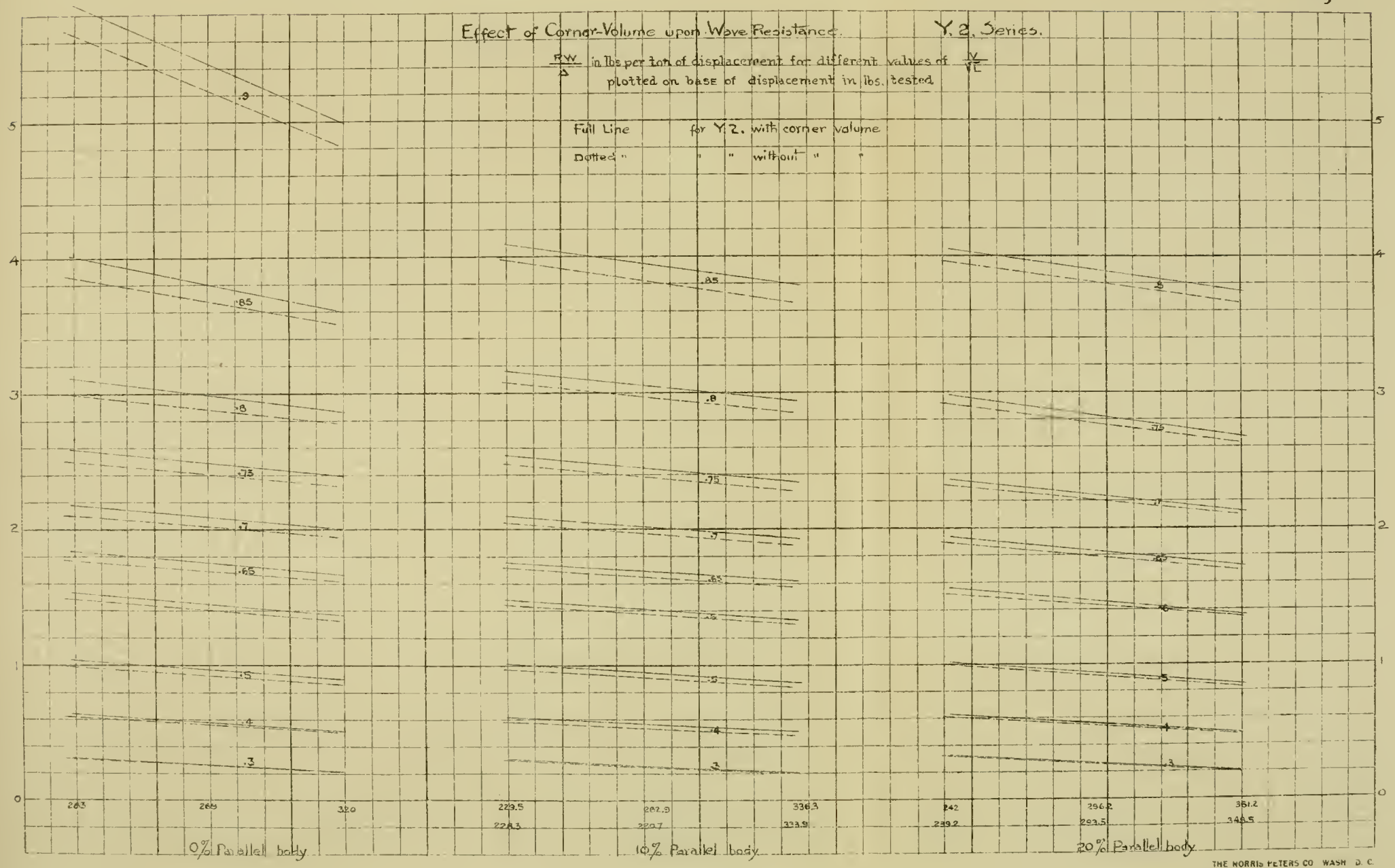
Fig. 9.



THE NORRIS PETERS CO., WASH., D. C.

To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.

Fig. 10.



THE NORRIS PETERS CO WASH D. C.

To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.

Y. 1c.

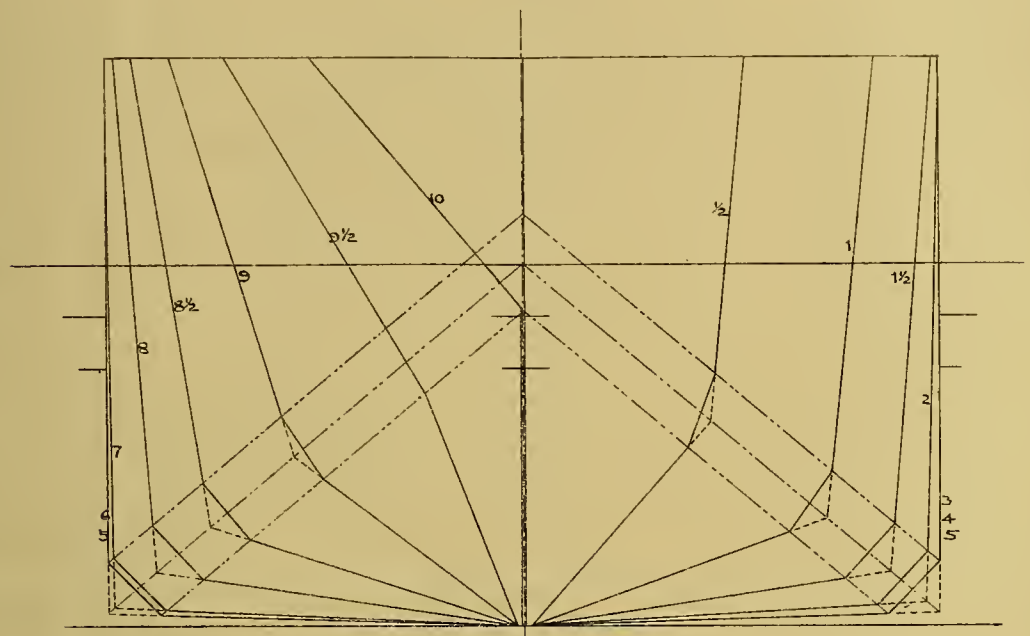
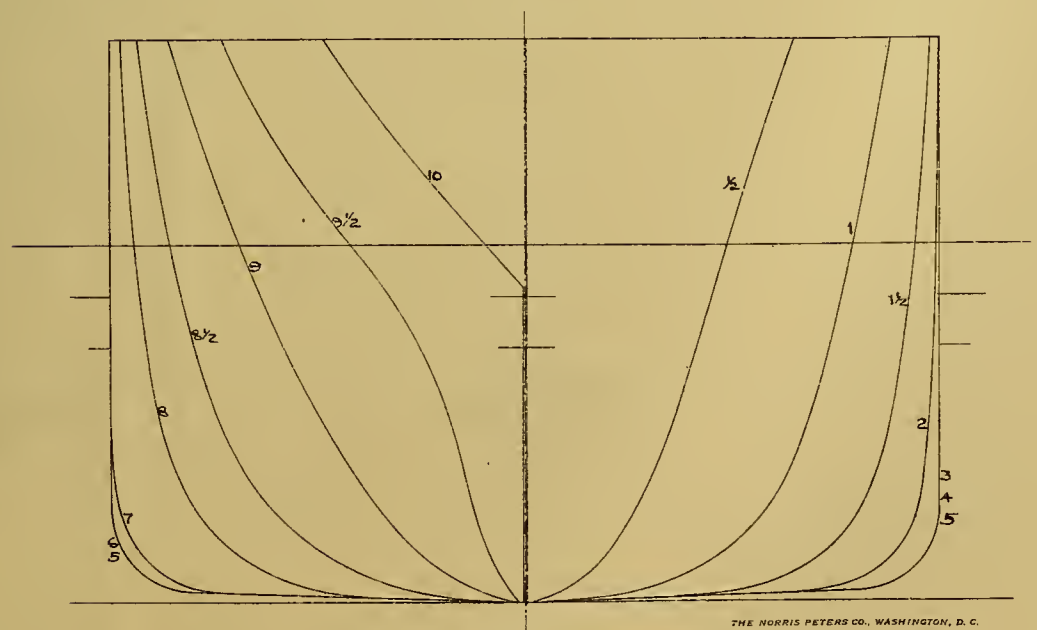


Fig. 11.

Y. 3c.

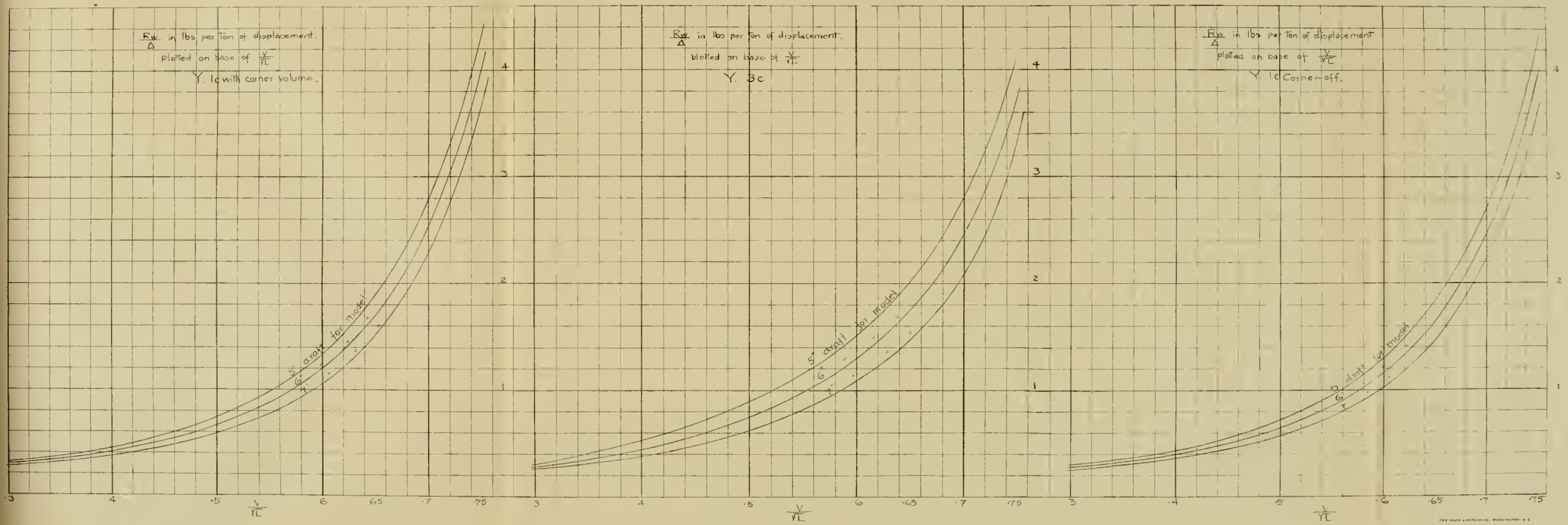


THE NORRIS PETERS CO., WASHINGTON, D. C.

Fig. 12.

To illustrate paper on "Experiments Upon Simplified Forms of Ships," by Professor Herbert C. Sadler, Member of Council.

Fig. 13.



To illustrate paper on "Variations of Shaft Horsepower, Propeller Revolutions, and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single Screw Cargo Ship," by Naval Constructor William McEntee, U. S. N., Member.

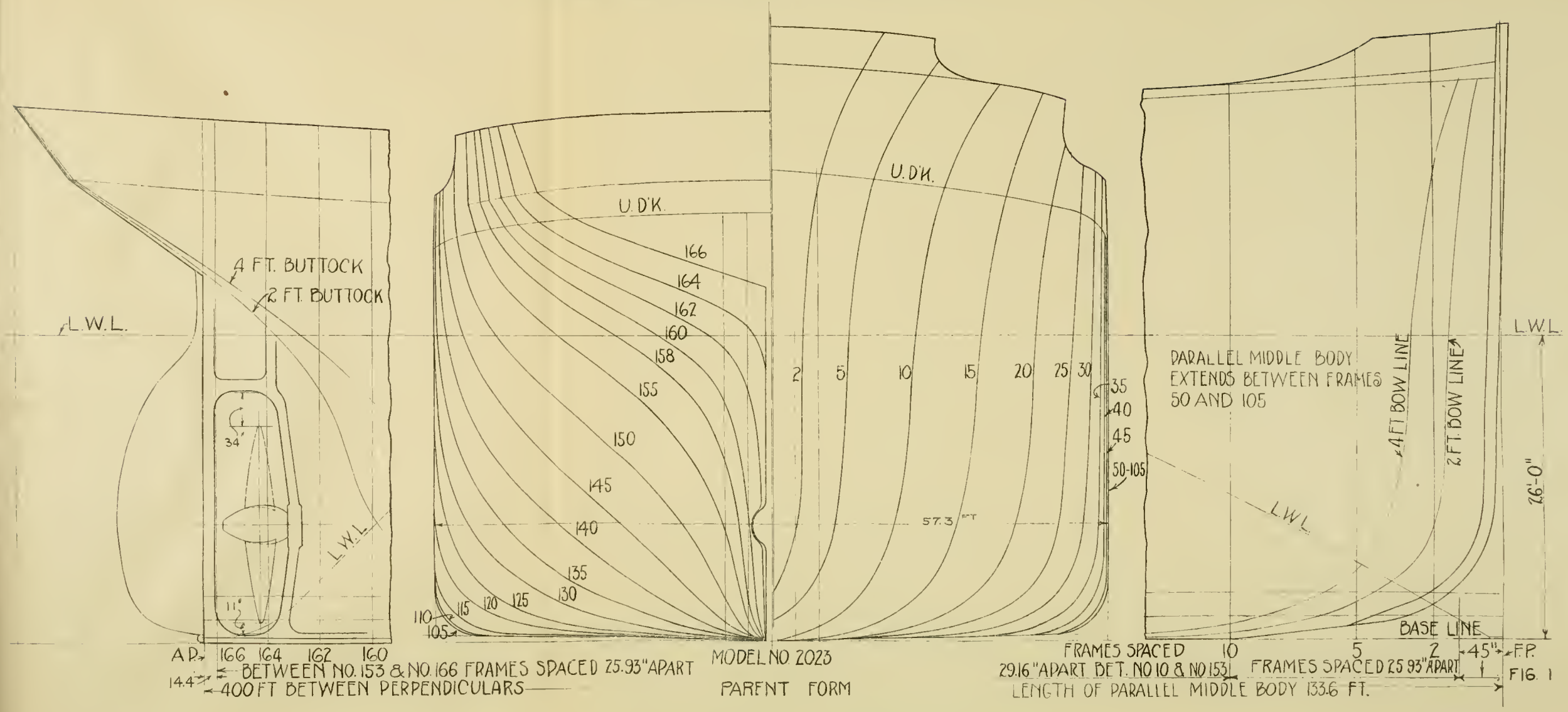


FIG. 1

To illustrate paper on "Variations of Shaft Horsepower, Propeller Revolutions, and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single Screw Cargo Ship," by Naval Constructor William McEntee, U. S. N., Member.

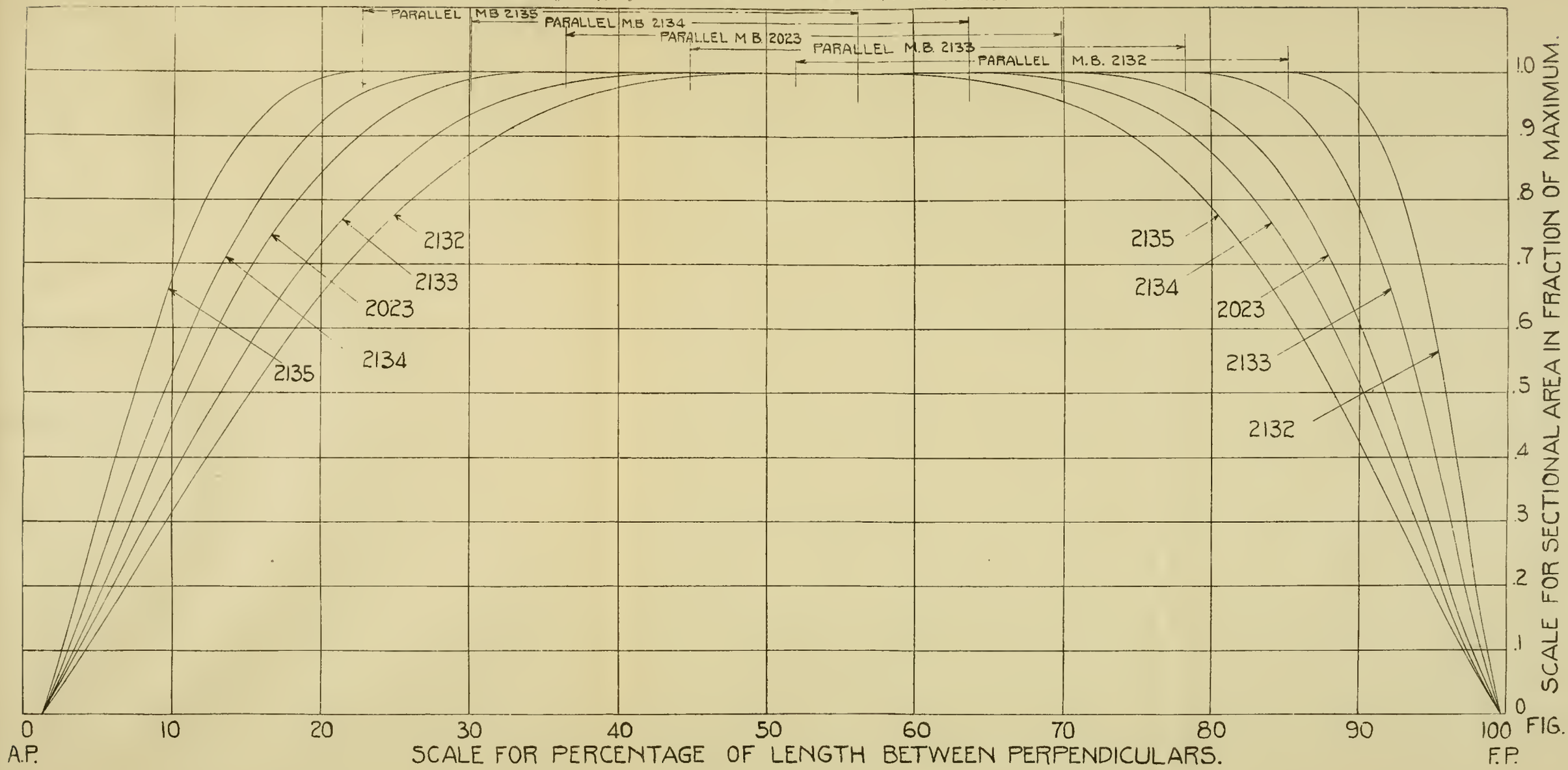


FIG. 2.

To illustrate paper on "Variations of Shaft Horsepower, Propeller Revolutions, and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single Screw Cargo Ship," by Naval Constructor William McEntee, U. S. N., Member.

DYNAMOMETER CARD SHOWING PROPELLER THRUST, TORQUE, AND R.P.M.

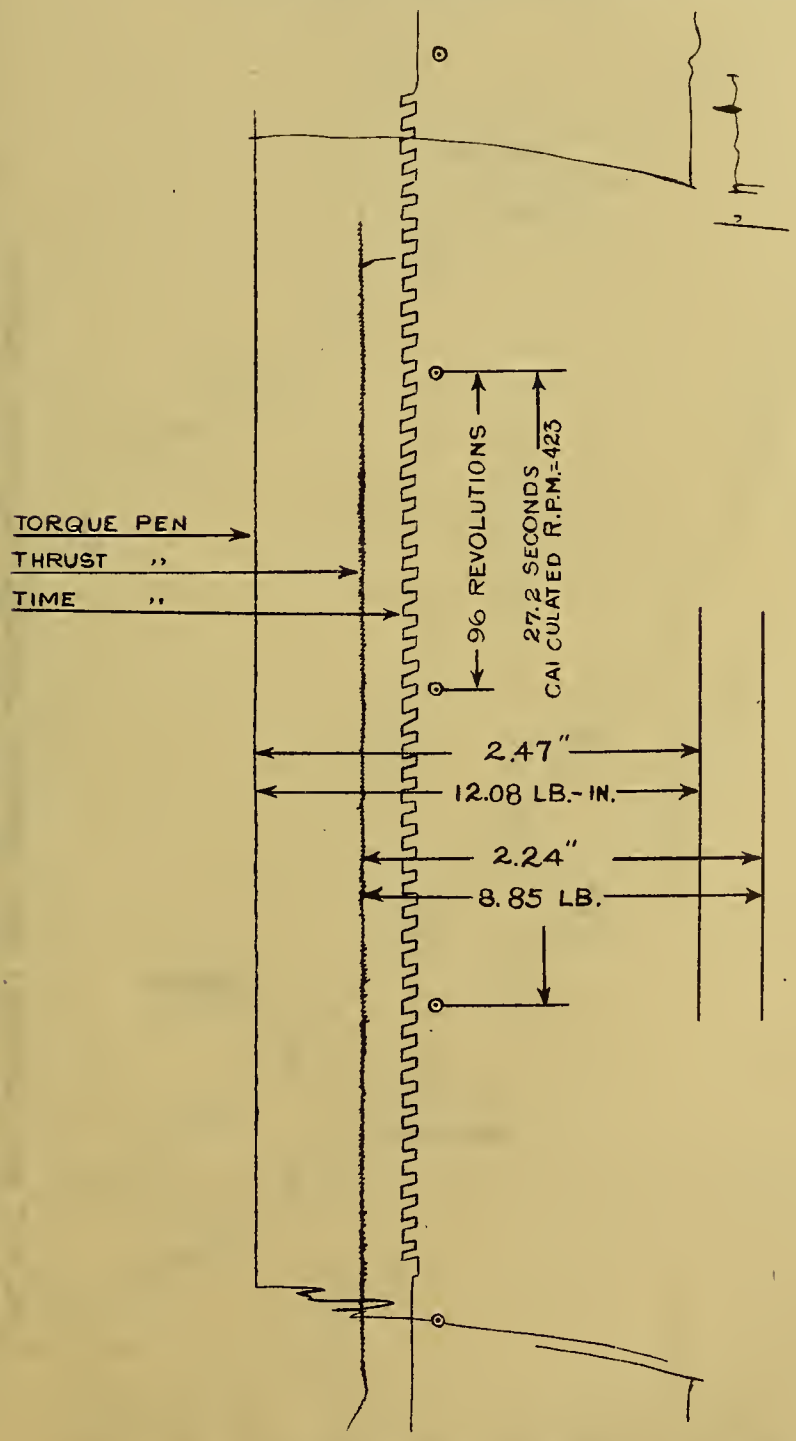
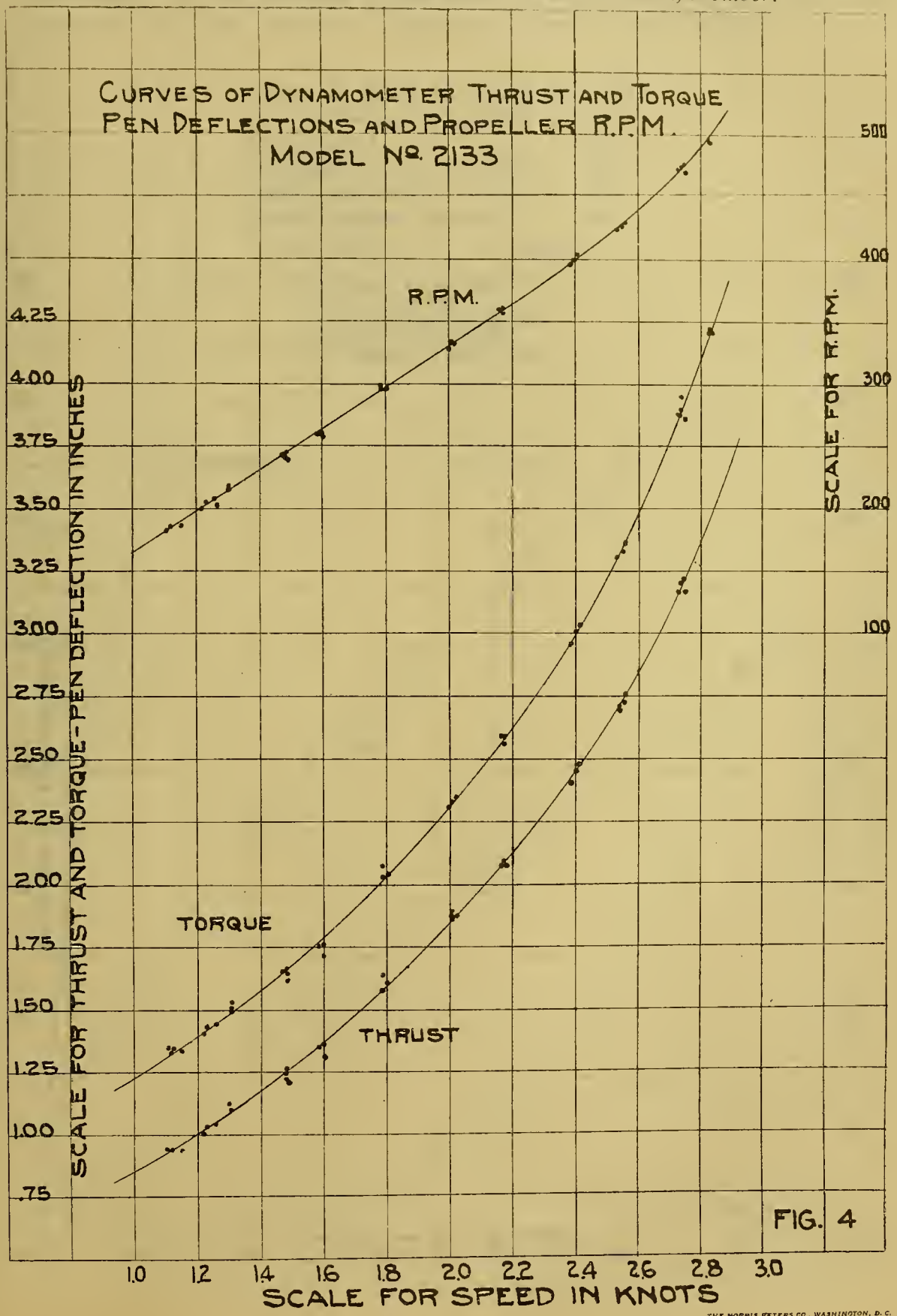


FIG. 3

THE NORRIS PETERS CO., WASHINGTON, D. C

To illustrate paper on "Variations of Shaft Horsepower, Propeller Revolutions, and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single Screw Cargo Ship," by Naval Constructor William McEntee, U. S. N., Member.



THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Variations of Shaft Horsepower, Propeller Revolutions, and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single Screw Cargo Ship," by Naval Constructor William McEntee, U. S. N., Member.

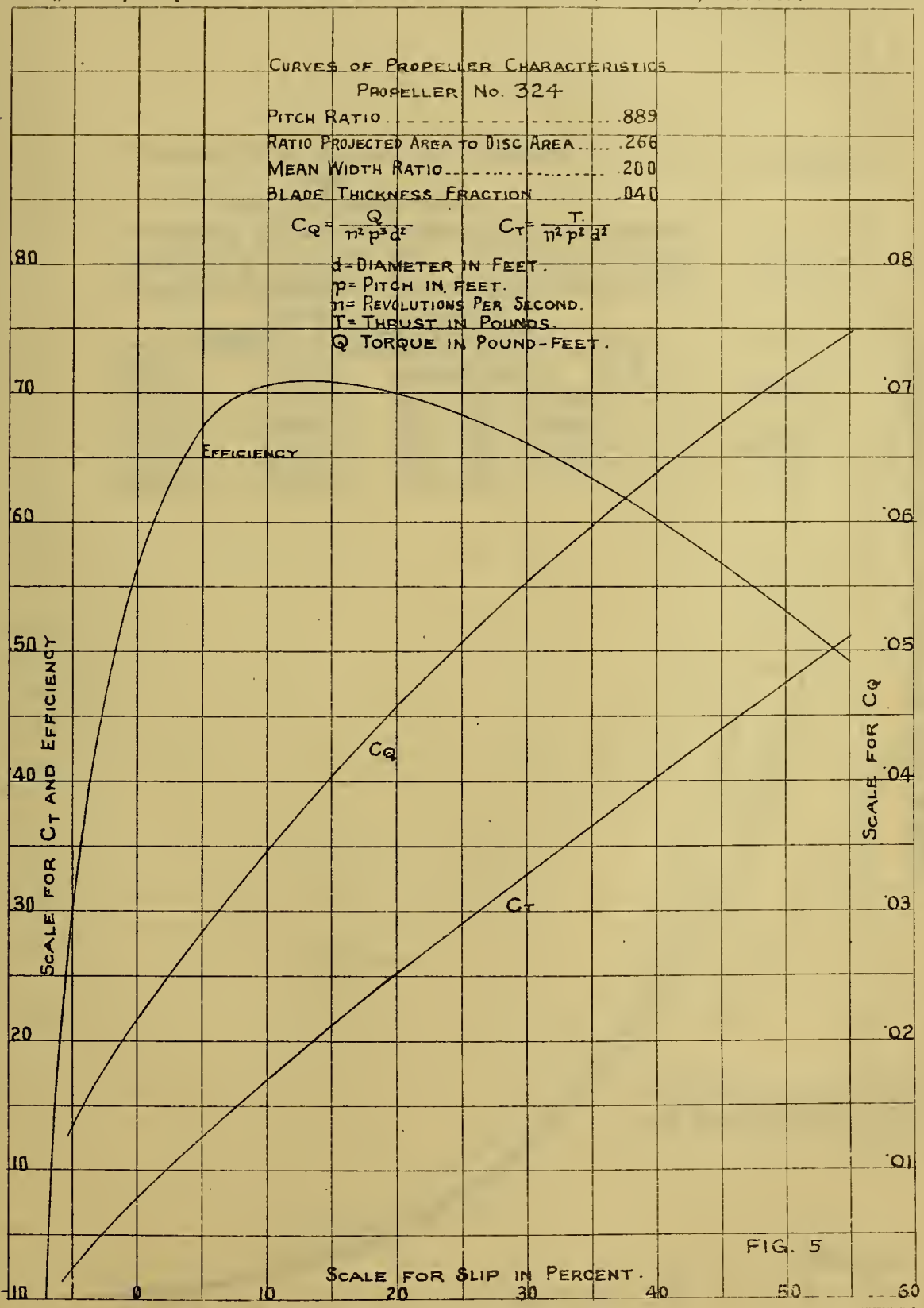
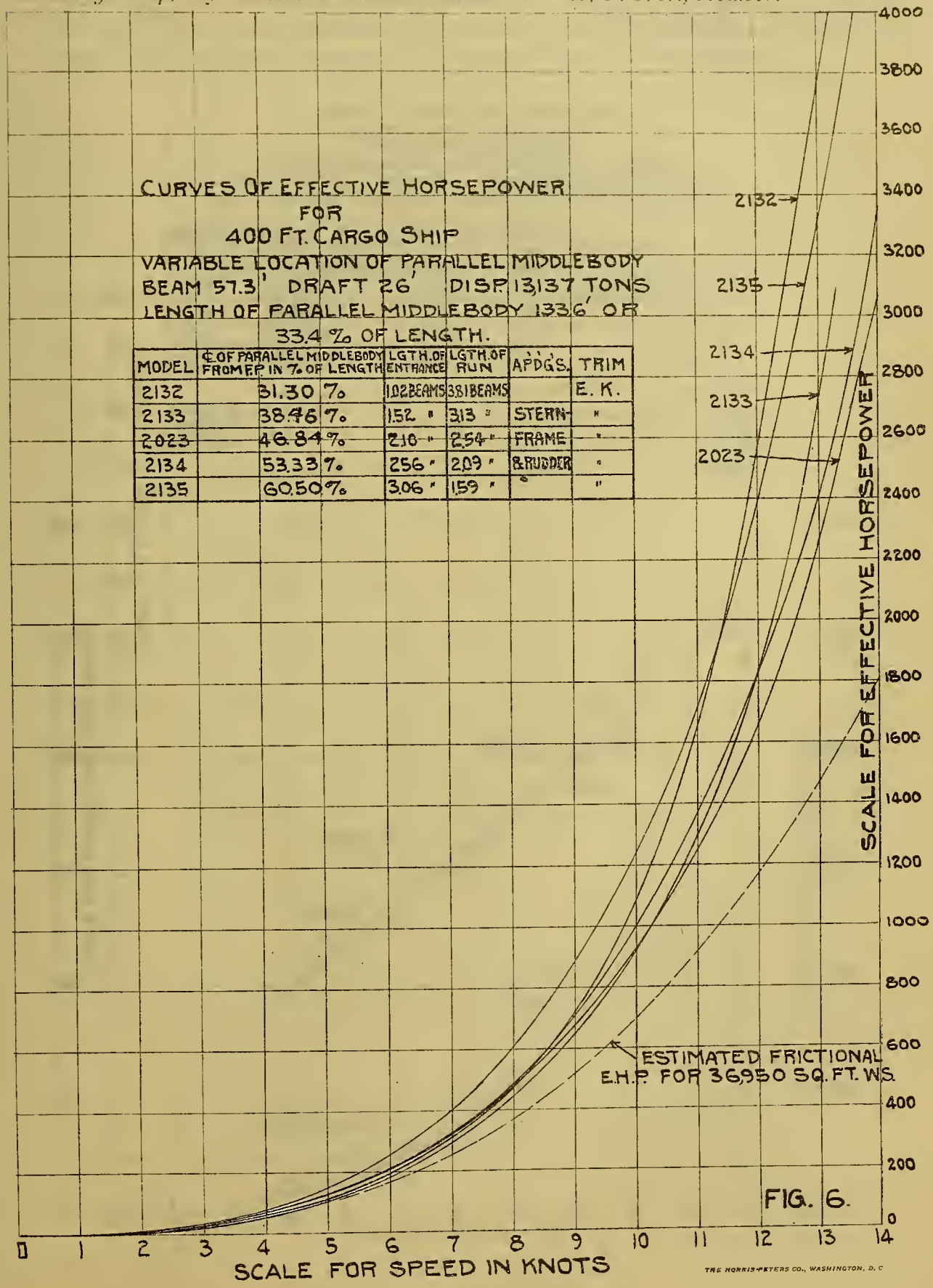


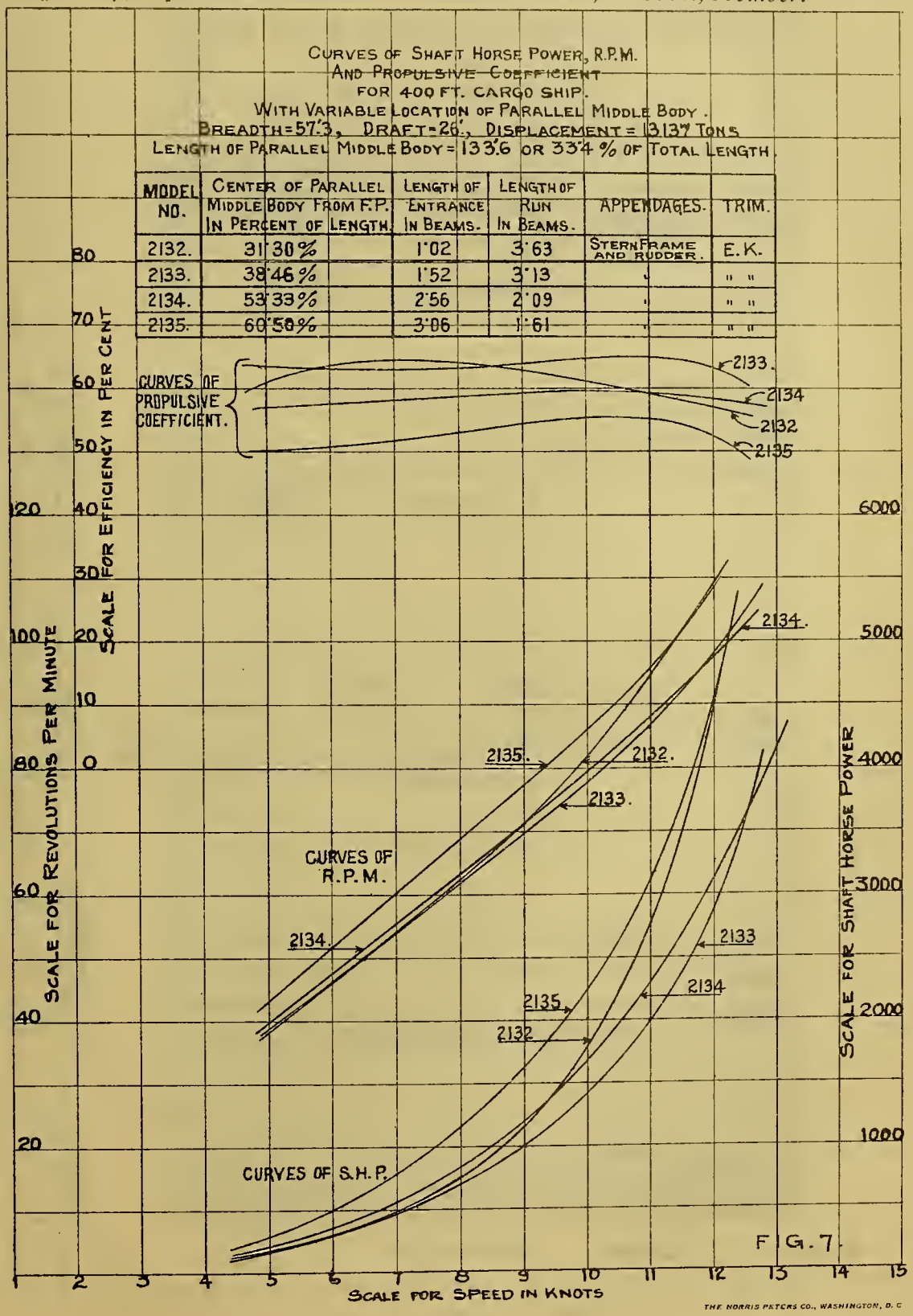
FIG. 5

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Variations of Shaft Horsepower, Propeller Revolutions, and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single Screw Cargo Ship," by Naval Constructor William McEntee, U. S. N., Member.



To illustrate paper on "Variations of Shaft Horsepower, Propeller Revolutions, and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single Screw Cargo Ship," by Naval Constructor William McEntee, U. S. N., Member.



THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Variations of Shaft Horsepower, Propeller Revolutions, and Propulsive Coefficient with Longitudinal Position of the Parallel Middle Body in a Single Screw Cargo Ship," by Naval Constructor William McEntee, U. S. N., Member.

CURVES OF WAKE FRACTION, THRUST DEDUCTION COEFFICIENT, TRUE SLIP AND APPARENT SLIP FOR

400 FT. CARGO SHIP

VARIABLE LOCATION OF PARALLEL MIDDLE BODY

BEAM = 57.'3 DRAFT = 26' DISP. = 13,137 TONS

LENGTH OF PARALLEL MIDDLE BODY = 133.'6 OR 33.'4 % OF LENGTH

MODEL NO.	CENTER OF PARALLEL MIDDLE BODY FROM F.P. IN PERCENT OF LENGTH	LENGTH OF ENTRANCE IN BEAM.	LENGTH OF RUN IN BEAM	APPENDAGES.	TRIM
2132	31.'30 %	1.'02	3.63	STERN FRAME AND RUDDER.	E. K.
2133	38.'46 %	1.'52	3.13	"	" "
2134	53.'33 %	2.'56	2.09	"	" "
2135	60.'50 %	3.'06	1.61	"	" "

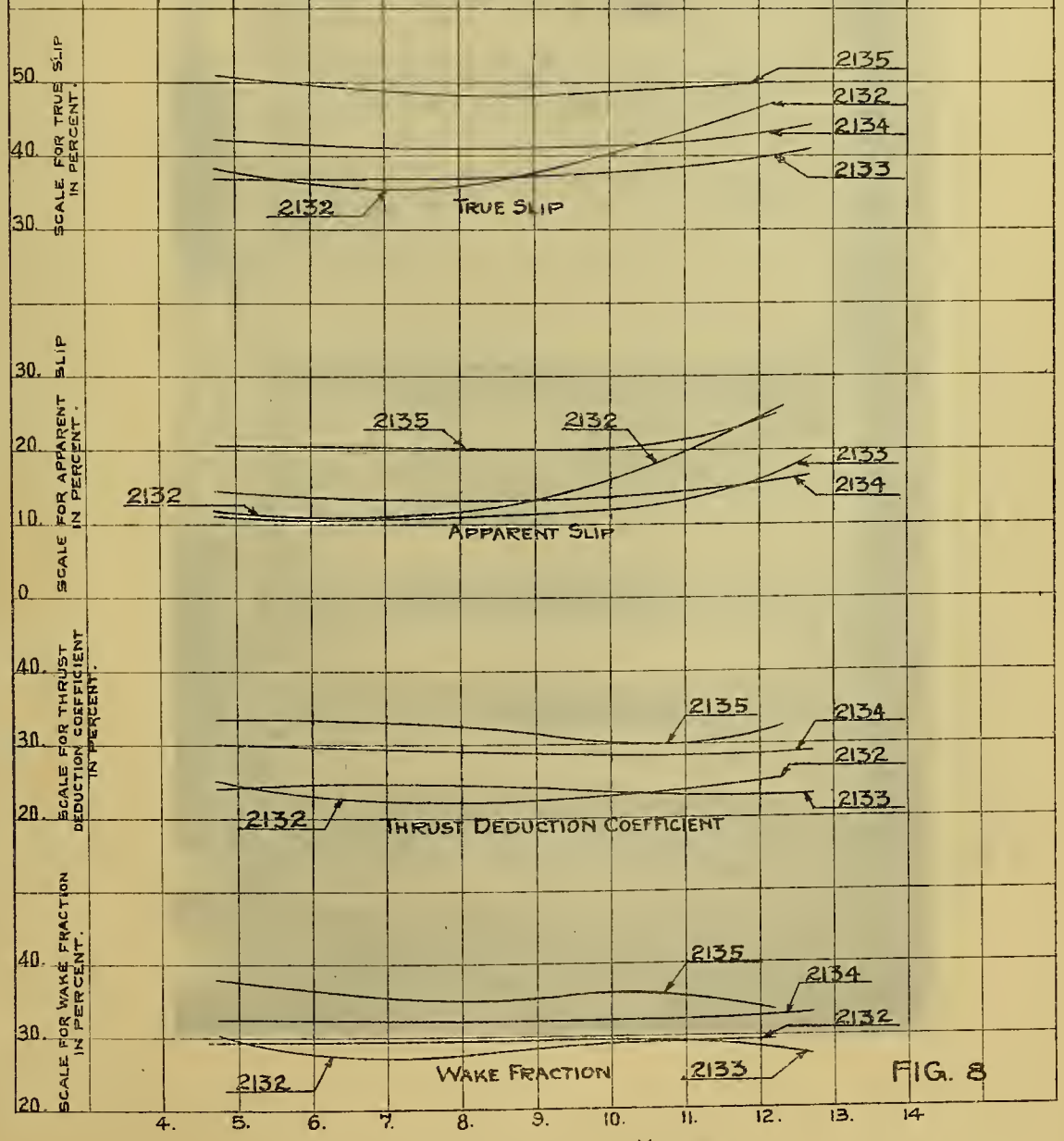


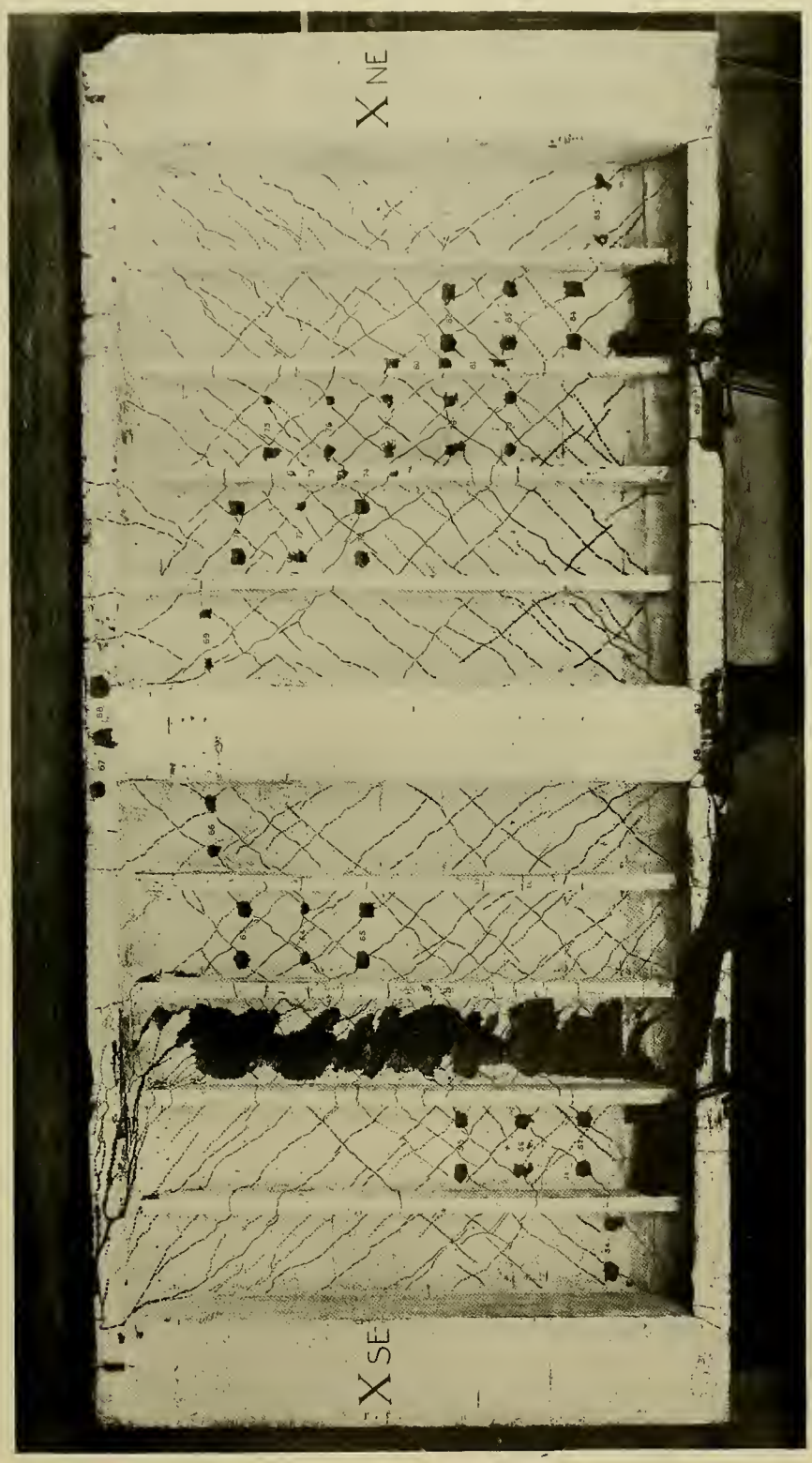
FIG. 8

THE NORRIS PETERS CO., WASHINGTON, D. C.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.

Concrete Beam, 22 Feet Long by 10 Feet High, Made and Tested to Determine Safe Shearing Strength of Reinforced Concrete. Above View Shows Beam After Application of Concentrated Load at the Center in One Direction. Cracks Painted to Make Them Visible.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



Same Beam as Shown in Plate 104, After Application to Failure of Concentrated Load in Inverted Position. Cracks Painted to Make Them Visible.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.

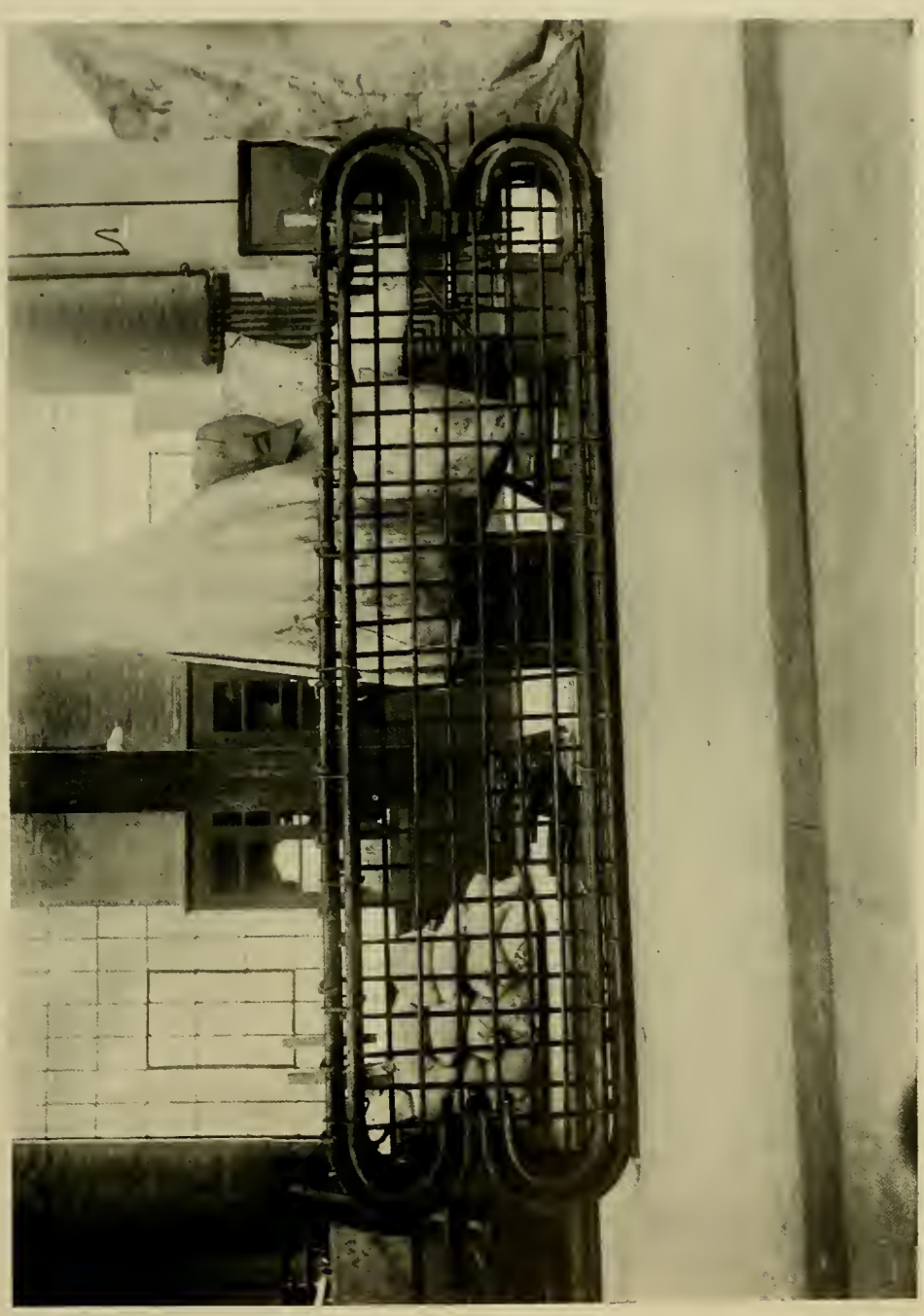
Concrete Ship Frame in Position in 10,000,000 Pounds Capacity Testing Machine, Bureau of Standards, Pittsburgh Pa., Ready for Test. The Frame is Full Sized in All Respects Except Length of Span, Which Has Been Reduced from 46 Feet to 22 Feet.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.

One Side of Frame After Application of Load. Cracks Painted for Photographing.

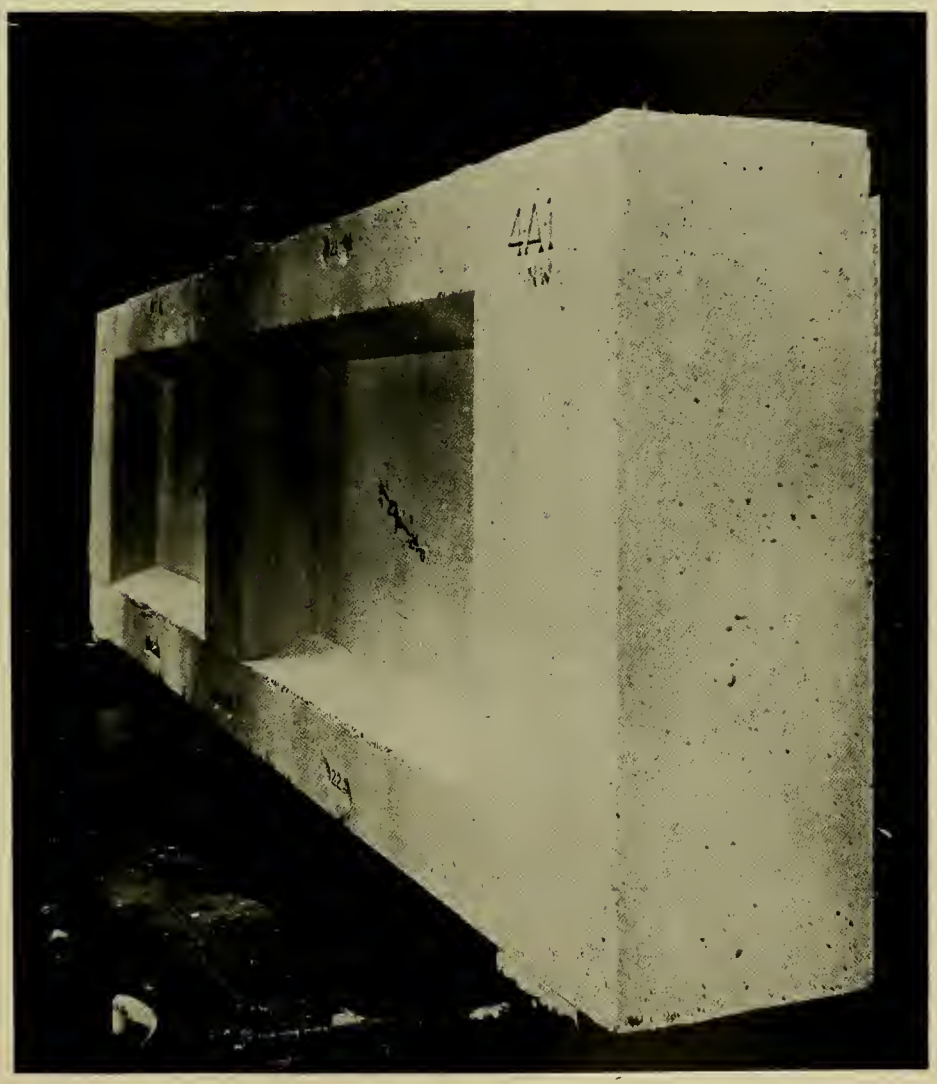
Opposite Side of Same Frame Shown Above.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



Reinforcing Steel for Concrete Beam 36 Inches Deep by 10 Feet 8 Inches Long, Made in an Investigation of Shearing Strength of Reinforced Concrete. Tests Made in Laboratory of Lehigh University.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.

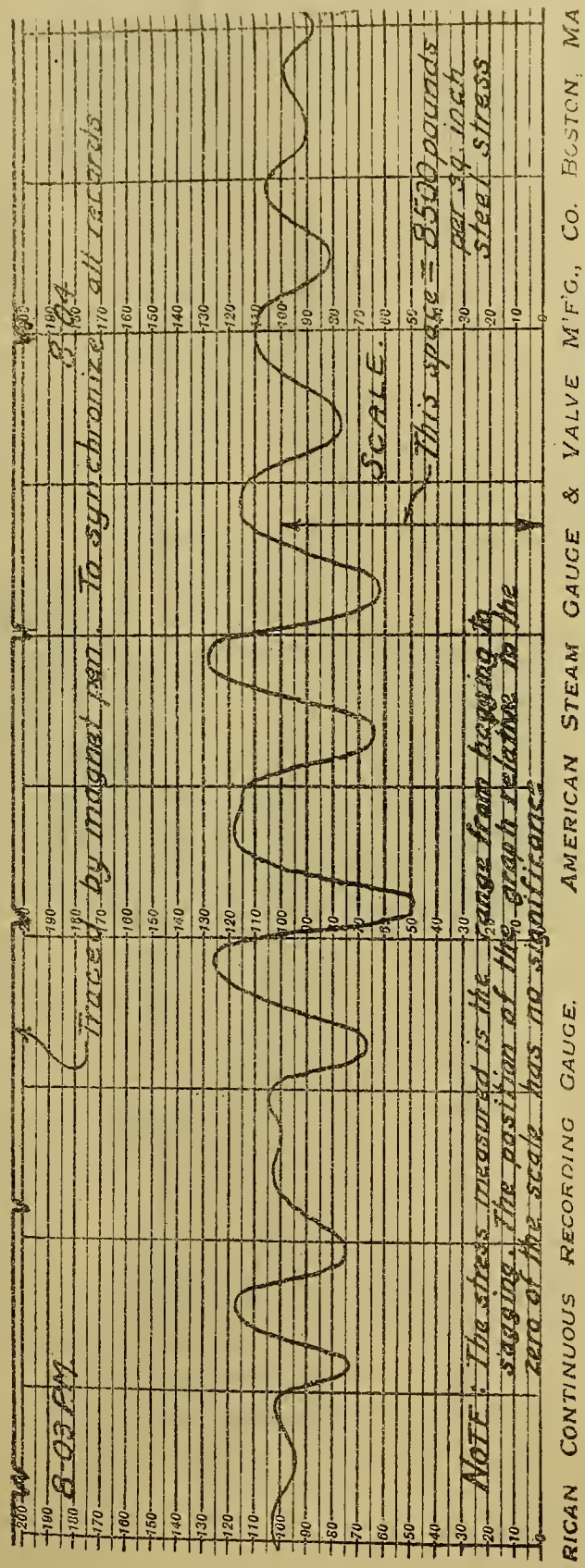


View of Complete Beam in Testing Machine Ready for Test.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.

Strainagraph or Recording Strain Gauge Used to Measure the Stress in Steel of Concrete Hull.

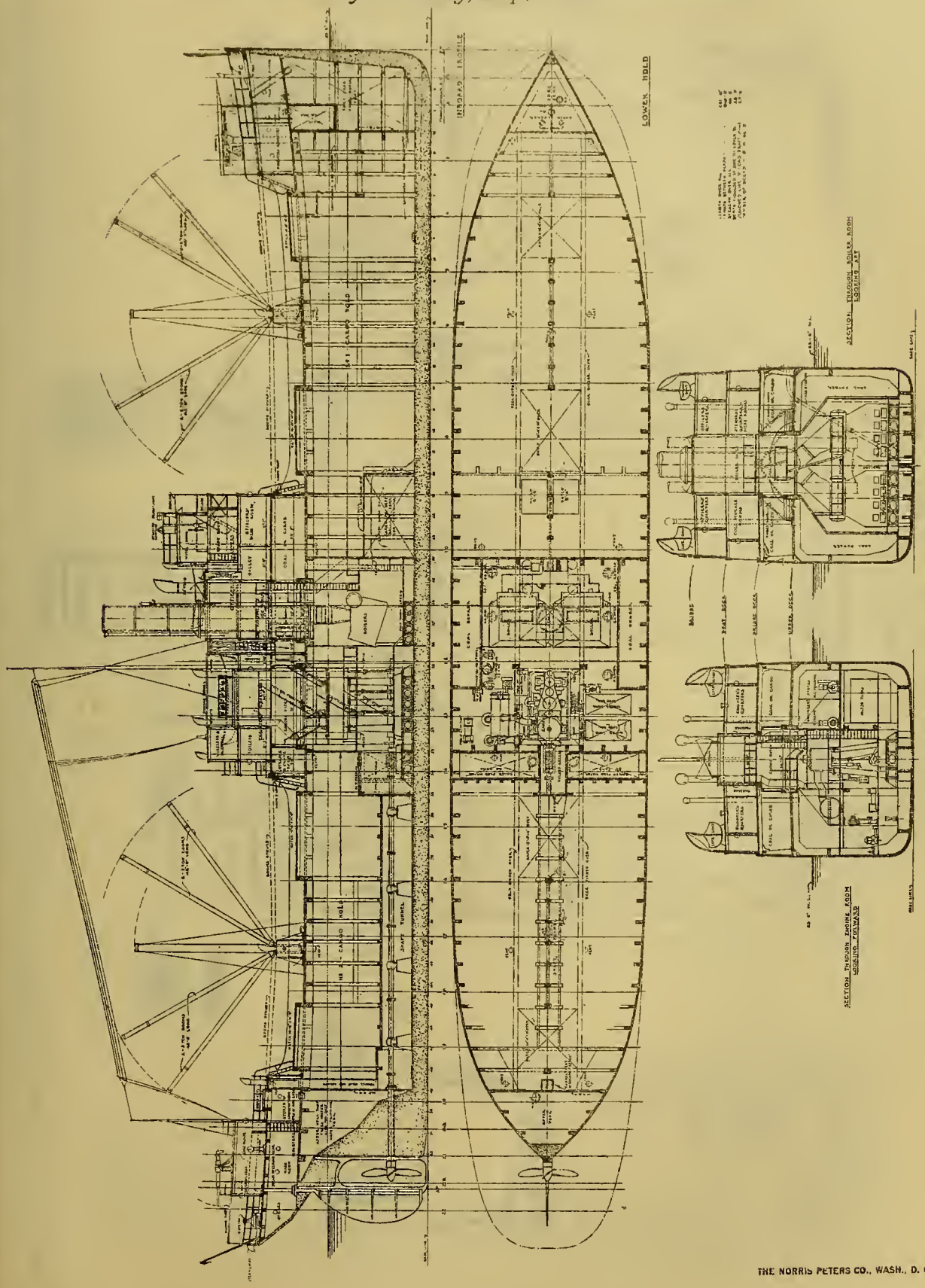
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



SPECIMEN STRAINAGRAPH RECORD TAKEN ON THE "FAITH" MAY 24, 1918. INSTRUMENT LOCATED AMIDSHIPS ON A LONGITUDINAL DECK BEAM ABOUT MIDWAY BETWEEN HATCHES 2 AND 3 AND ON A LINE ALONG THE PORT SIDE OF THESE HATCHWAYS. THE PEN WHEN TRAVELING UPWARD RECORDS COMPRESSION, WHEN TRAVELING DOWNWARD RECORDS EXTENSION.

THE NORRIS PETERS CO., WASH., D. C.

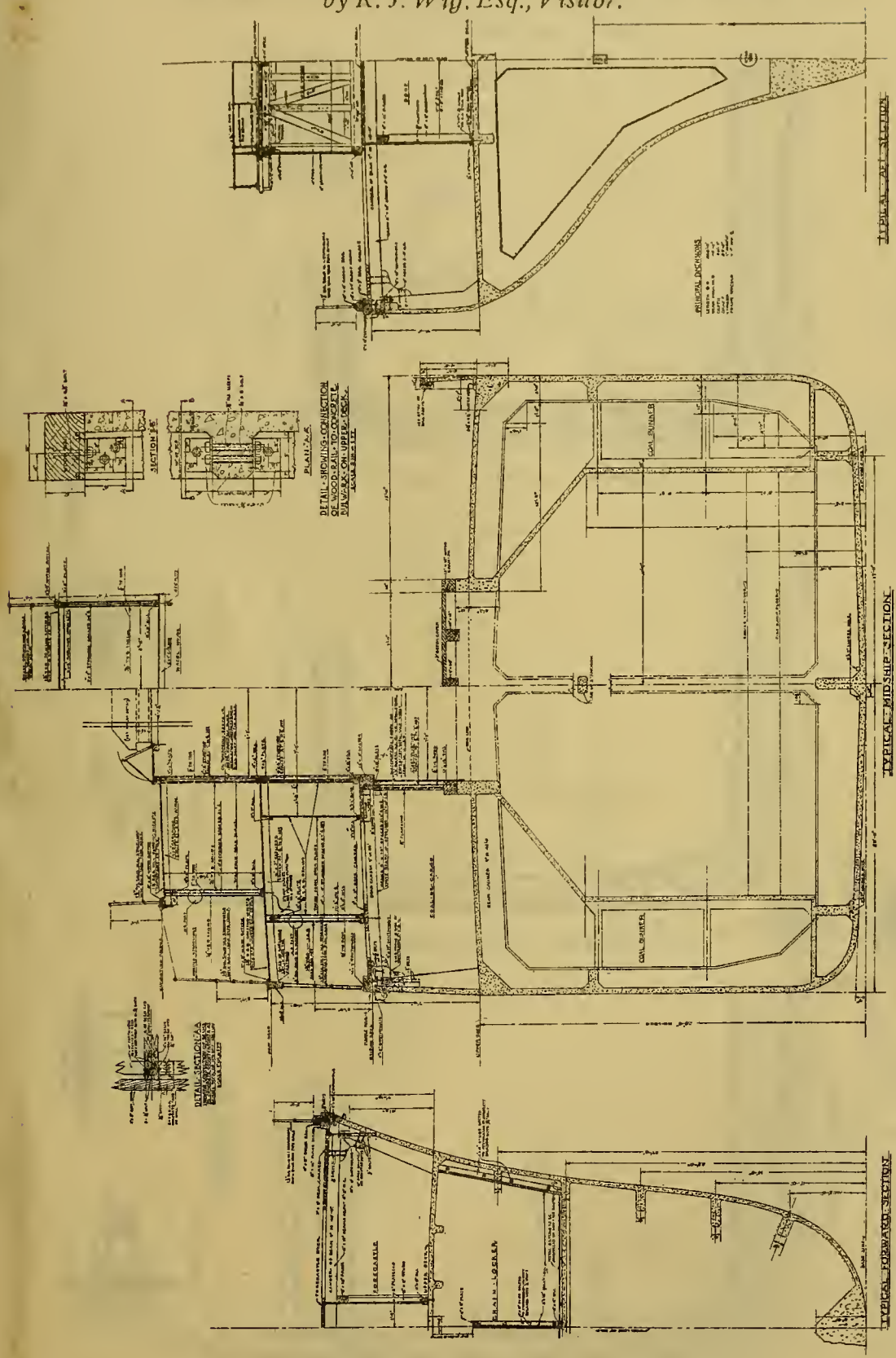
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



PROFILE OF 3,500-TON CONCRETE SHIP.

THE NORRIS PETERS CO., WASH., D. C.

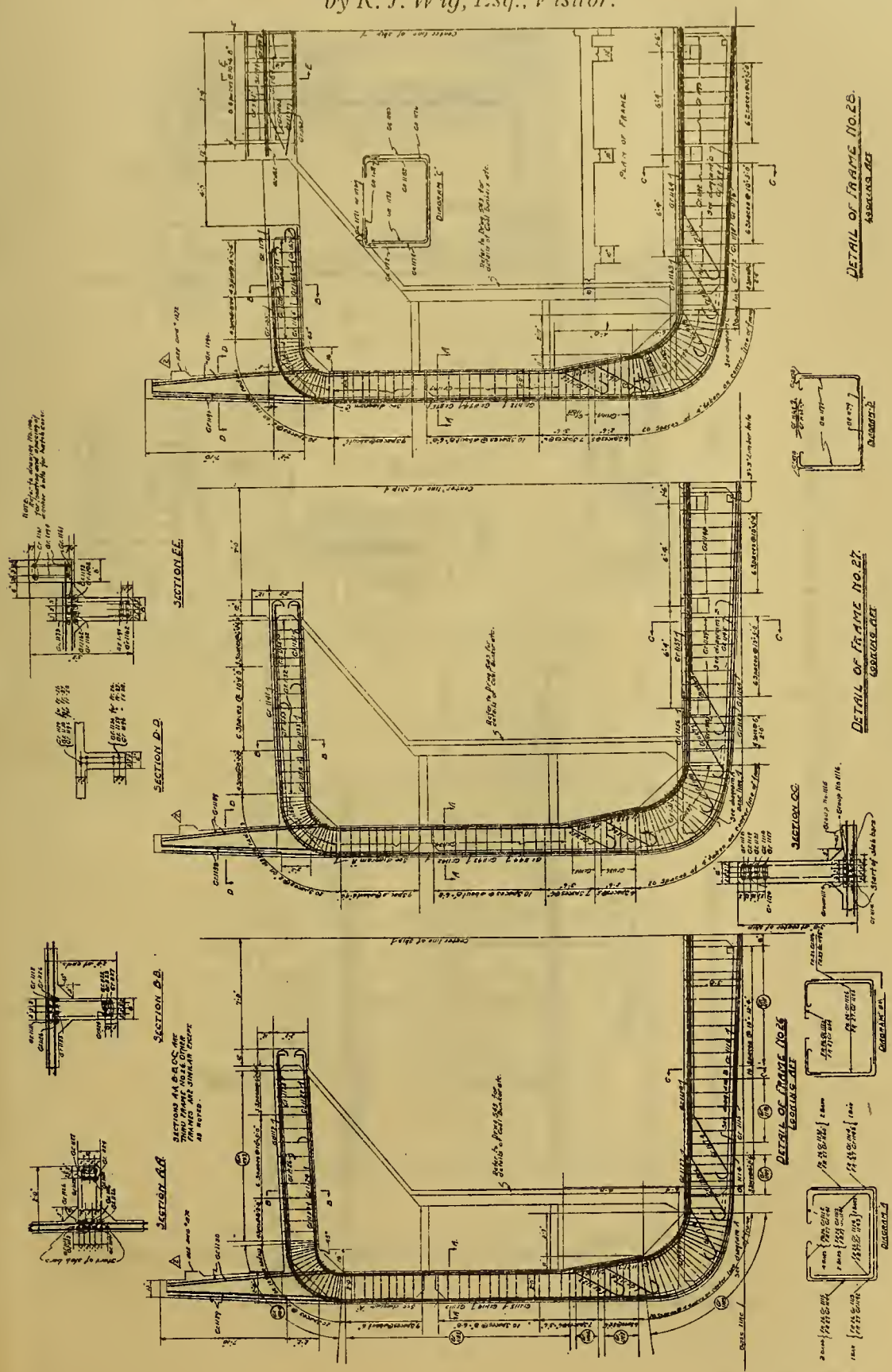
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



TRANSVERSE SECTION OF 3,500-TON CONCRETE CARGO SHIP.

THE NORRIS PETERS CO., WASH., D. C.

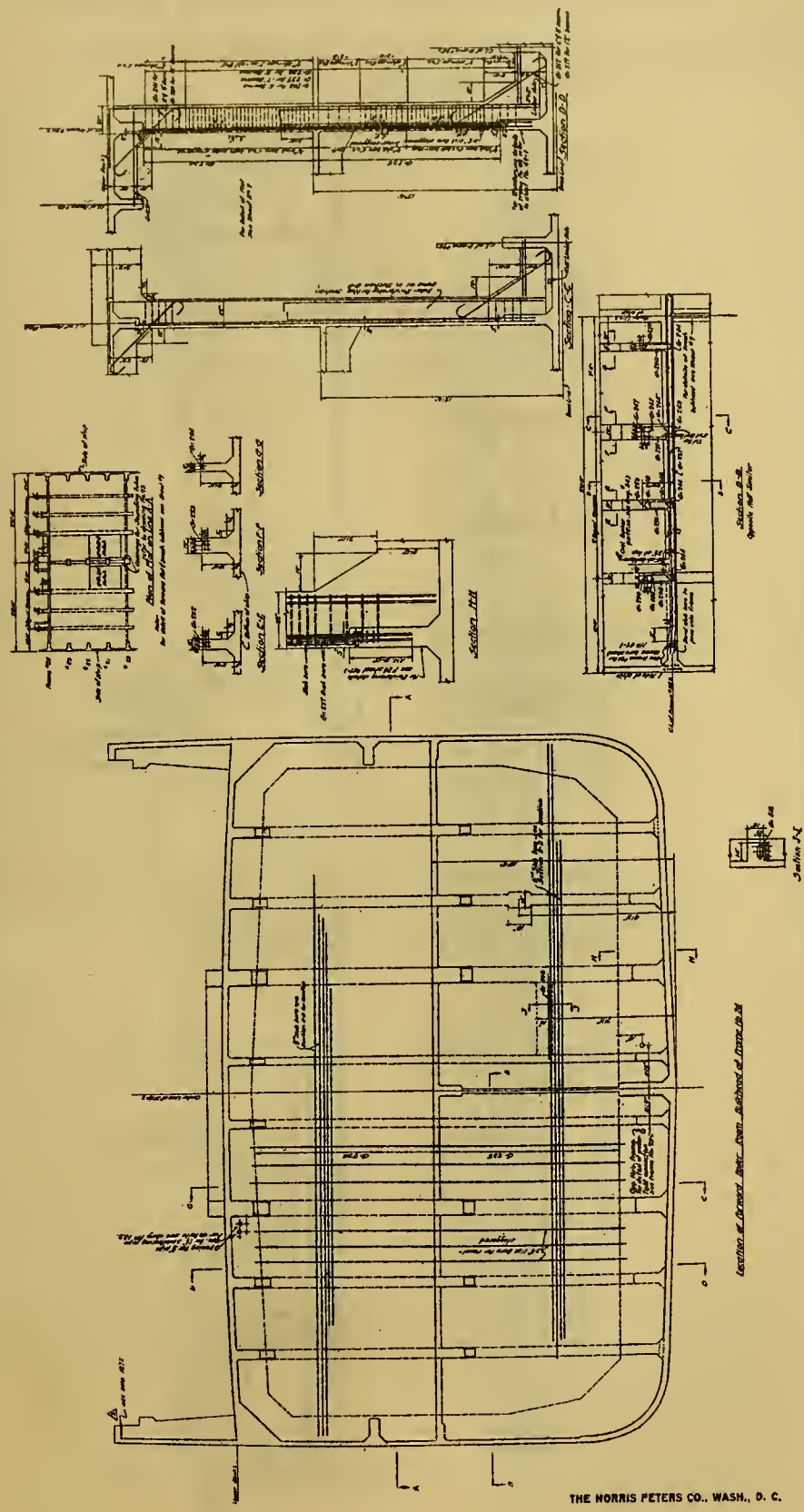
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



Typical Frame of 3,500-Ton Concrete Cargo Ship.

THE NORRIS PETERS CO., WASH., D. C.

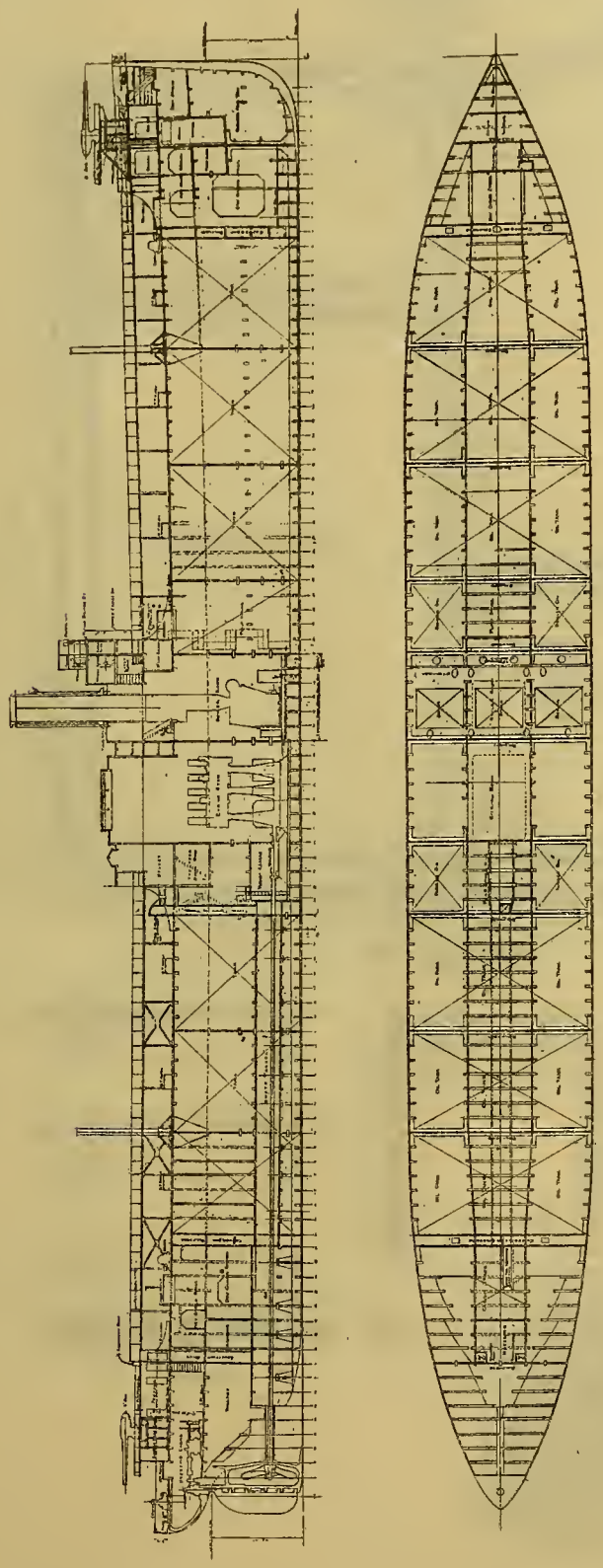
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



TYPICAL BULKHEAD OF 3,500-TON CONCRETE CARGO SHIP.

THE HORRIS PETERS CO., WASH., D. C.

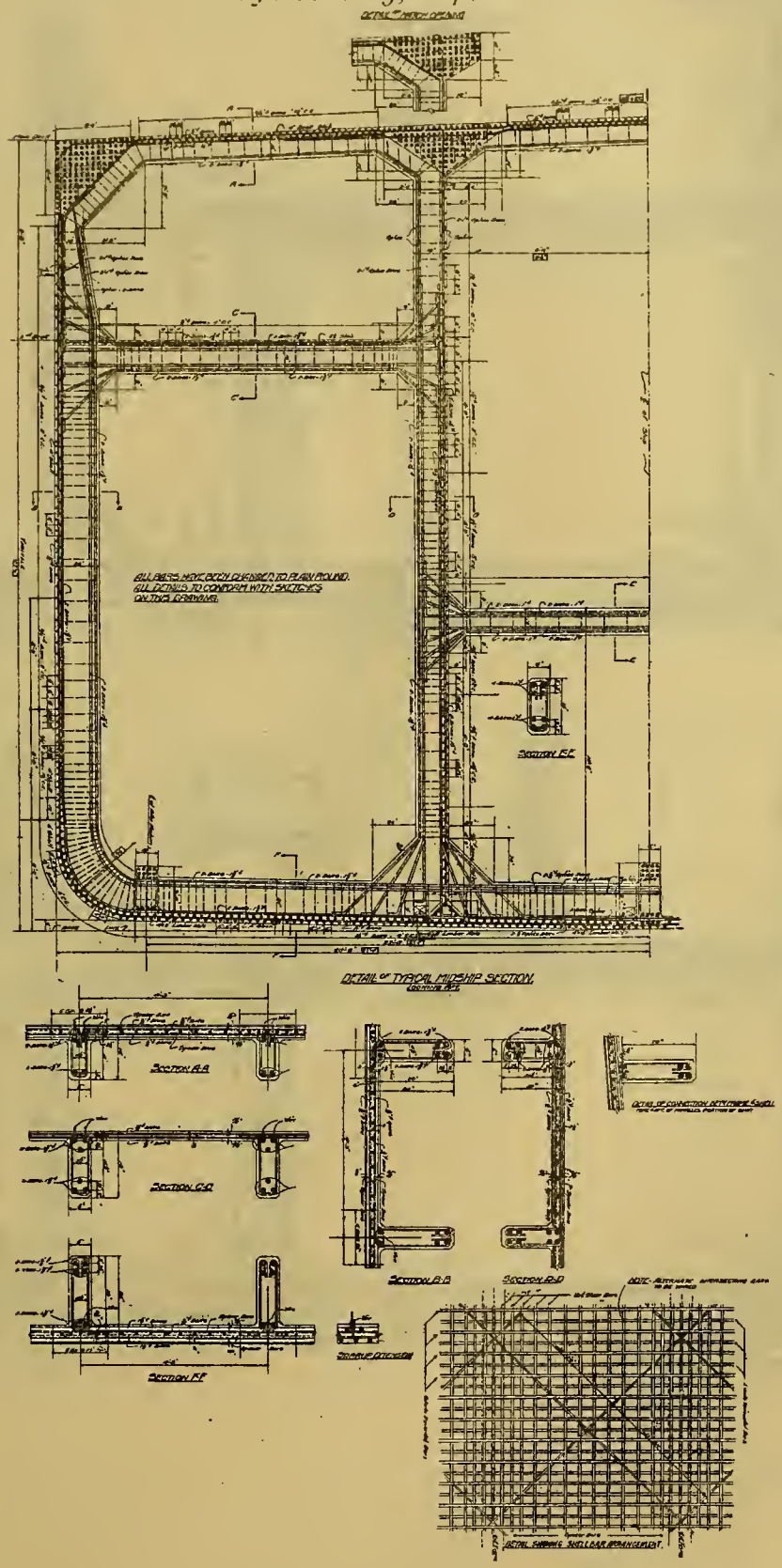
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



PROFILE OF 7,500-TON CONCRETE OIL TANKER.

THE NORRIS PETERS CO., WASH., D. C.

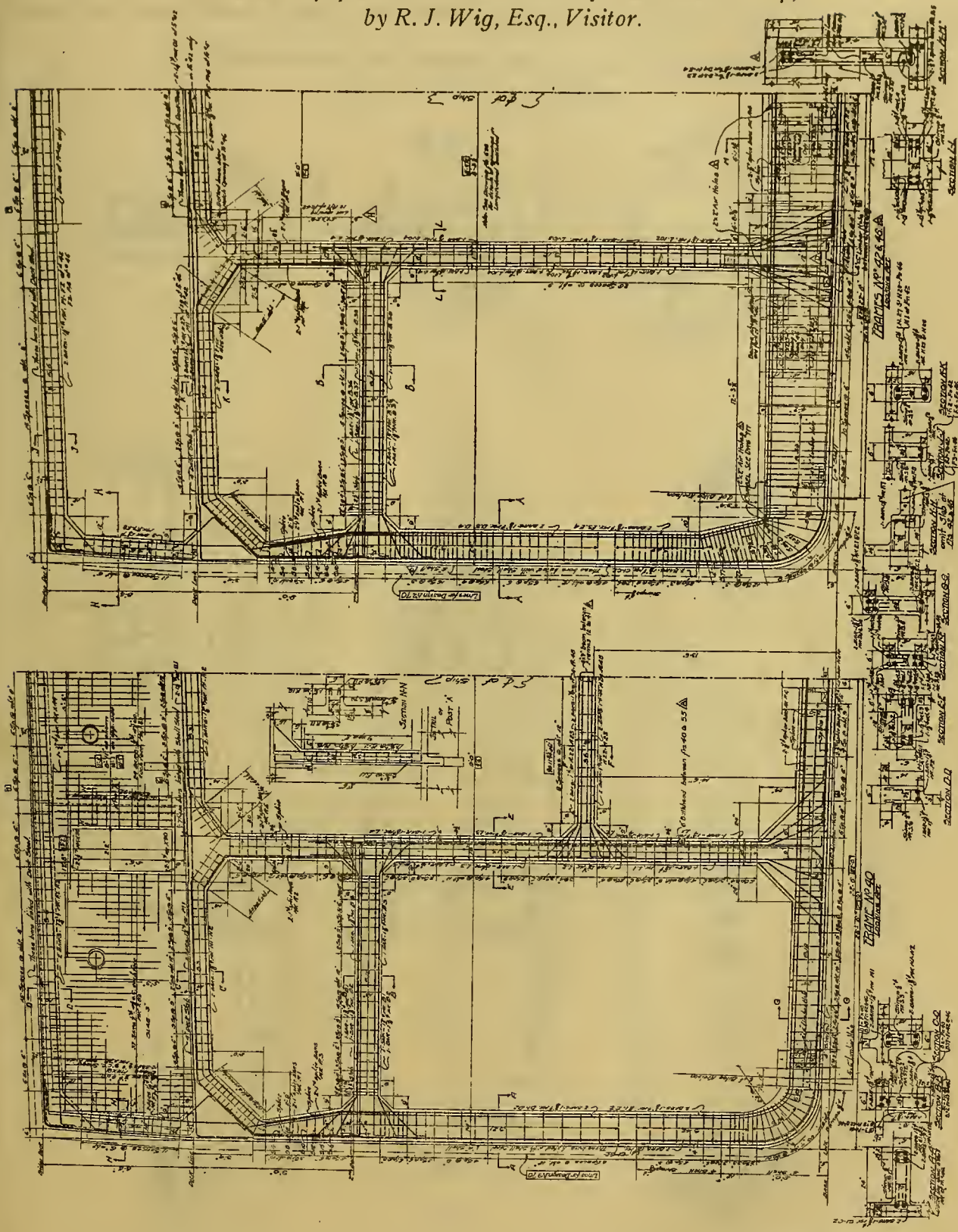
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



TYPICAL TRANSVERSE SECTION OF 7,500-TON CONCRETE OIL TANKER.

THE NORRIS PETERS CO., WASH., D. C.

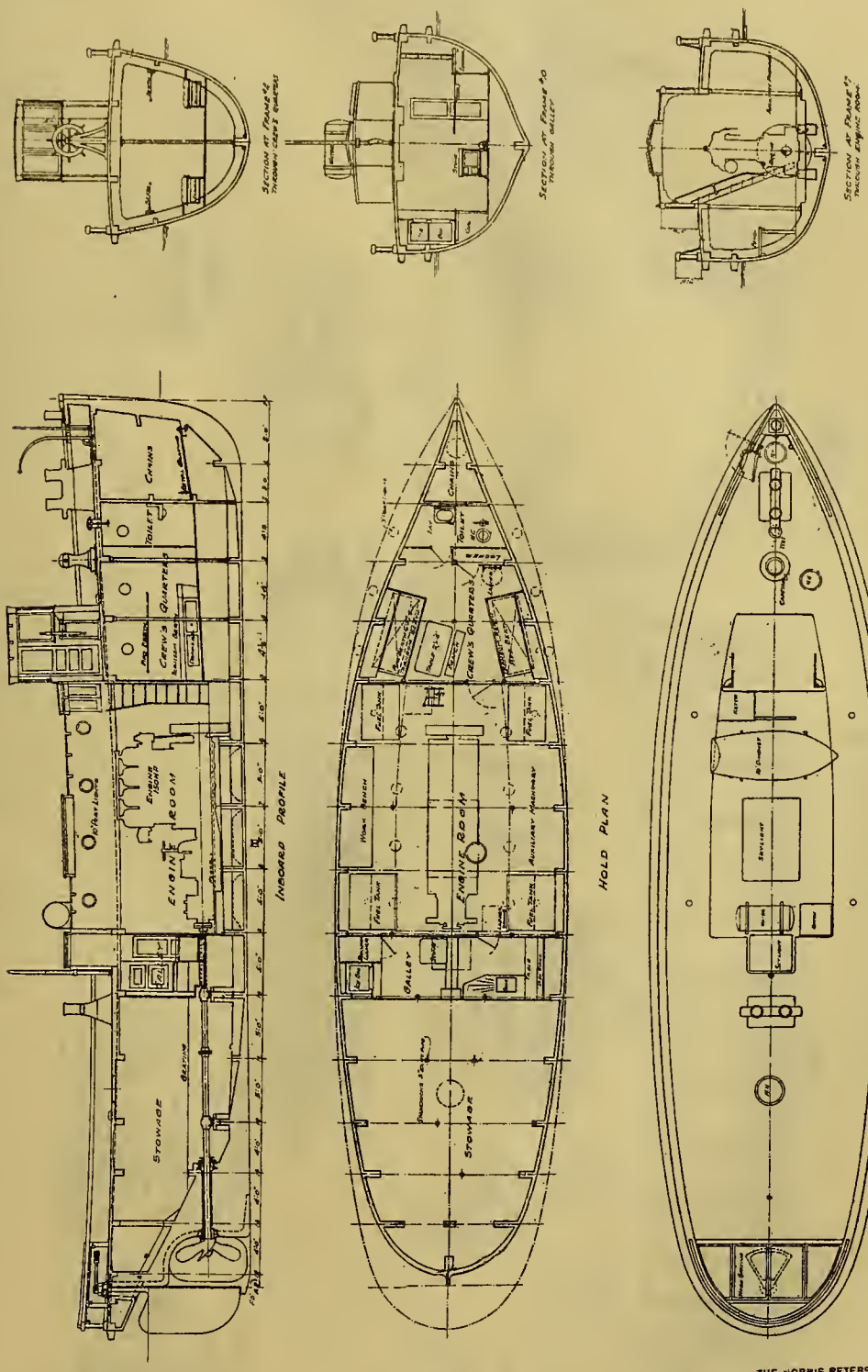
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



TYPICAL FRAME OF 7,500-TON CONCRETE OIL TANKER.

THE NORRIS PETERS CO., WASH., D. C.

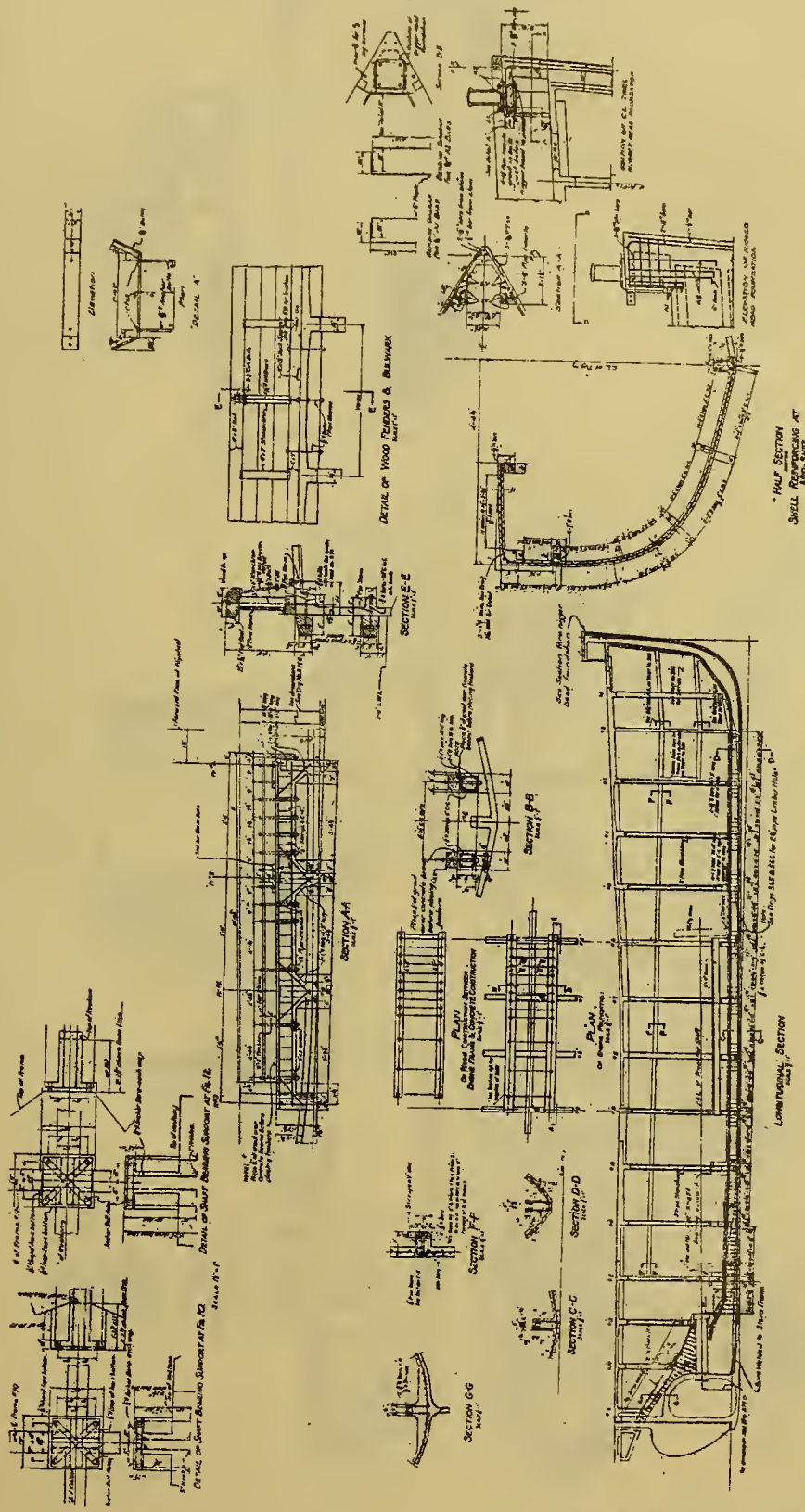
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



General Arrangement of 70-Foot Concrete Tug Boat.

THE NORRIS PETERS CO., WASH., D. C.

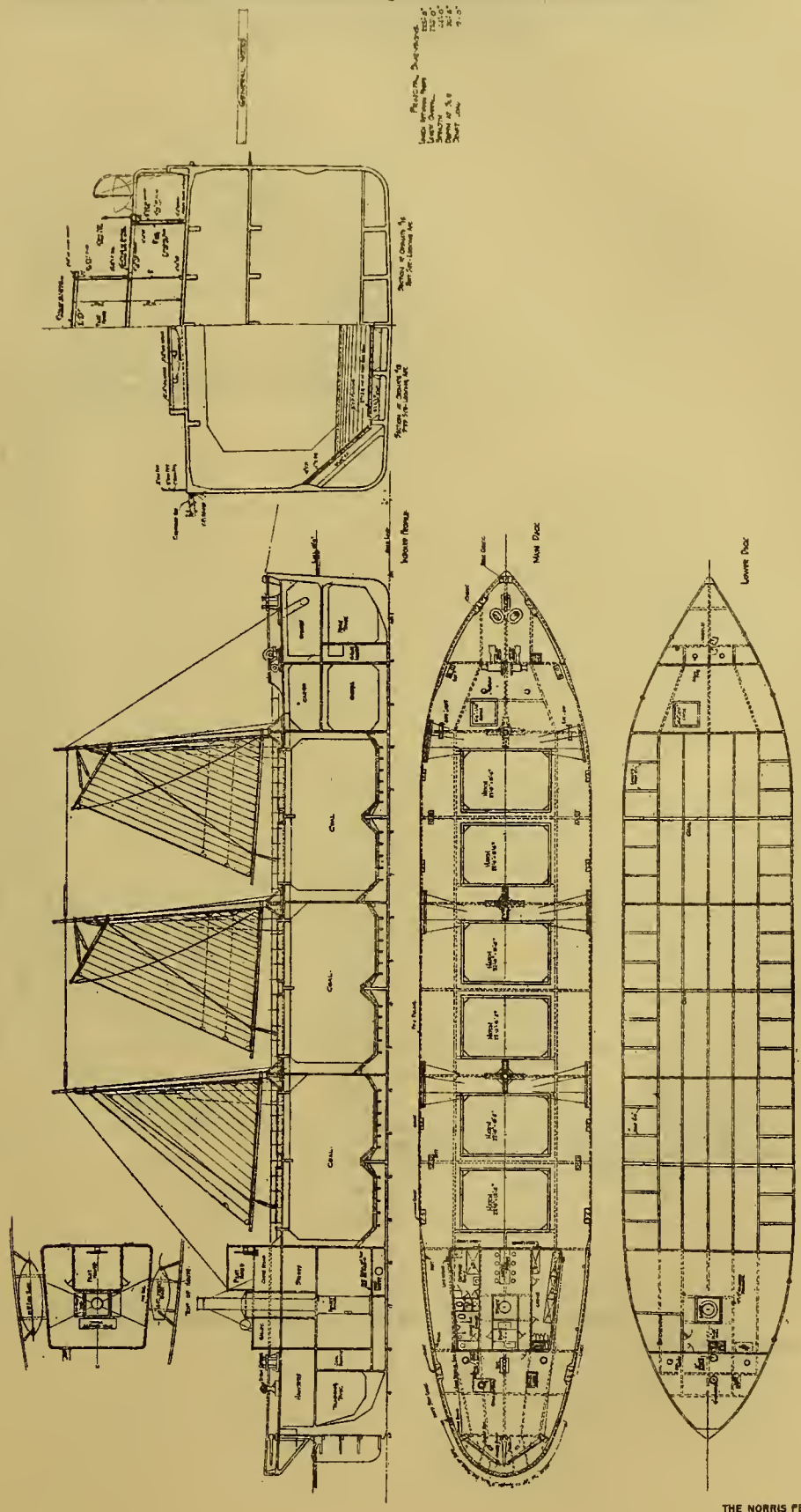
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



Transverse and Longitudinal Section of 70-Foot Concrete Tug Boat.

THE NORRIS PETERS CO., WASH., D. C.

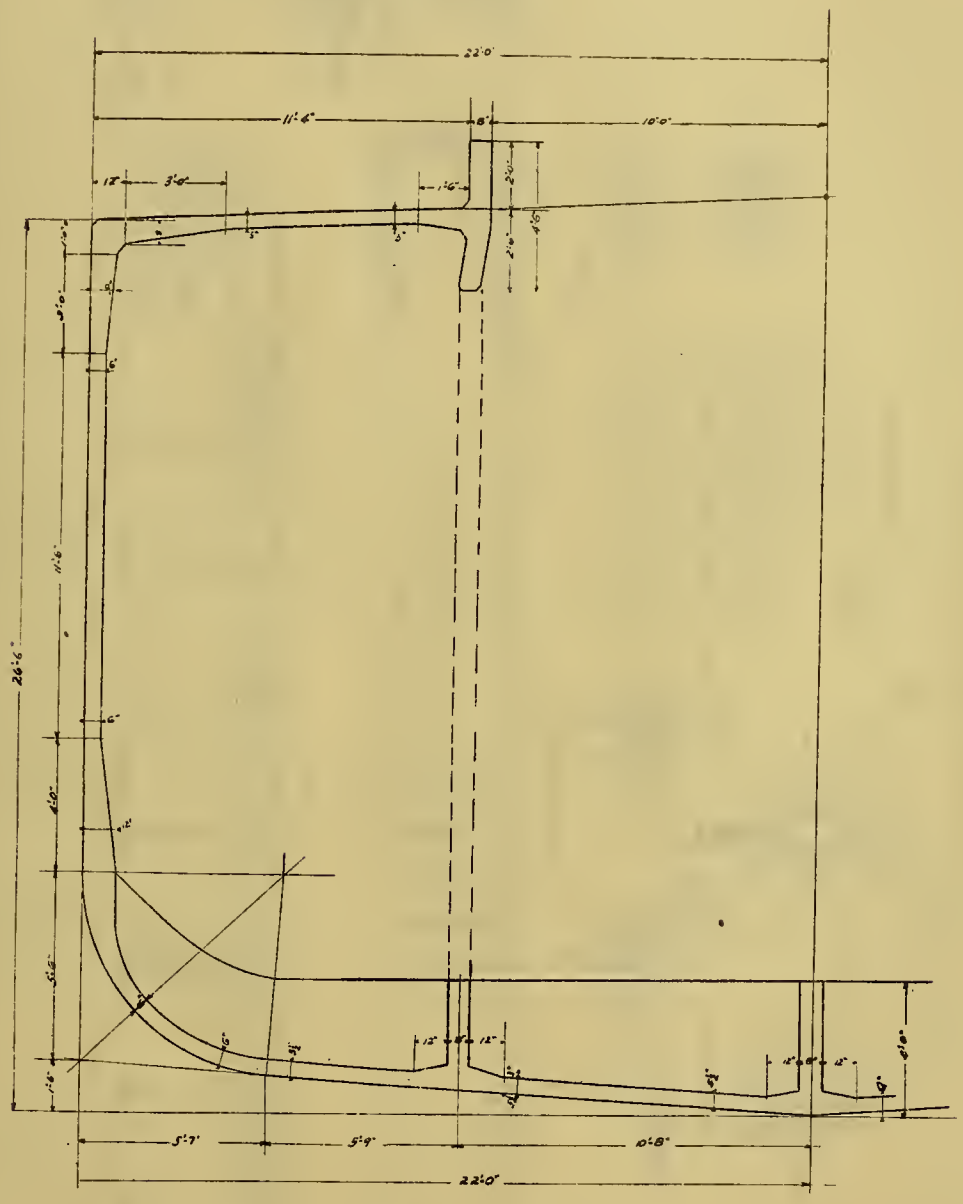
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



PROFILE 2,500-TON CONCRETE SCHOONER RIGGED COAL BARGE.

THE NORRIS PETERS CO., WASH., D. C.

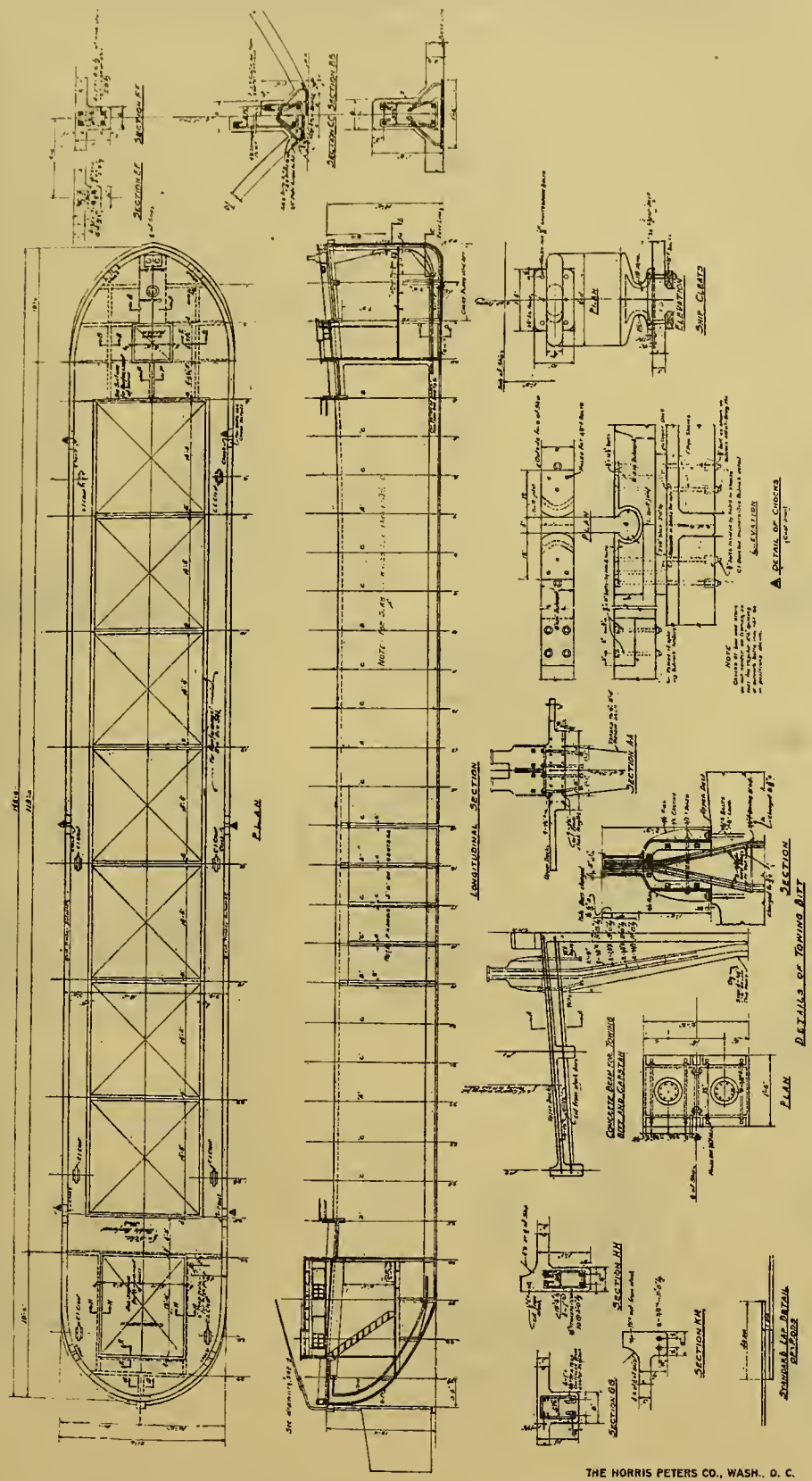
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



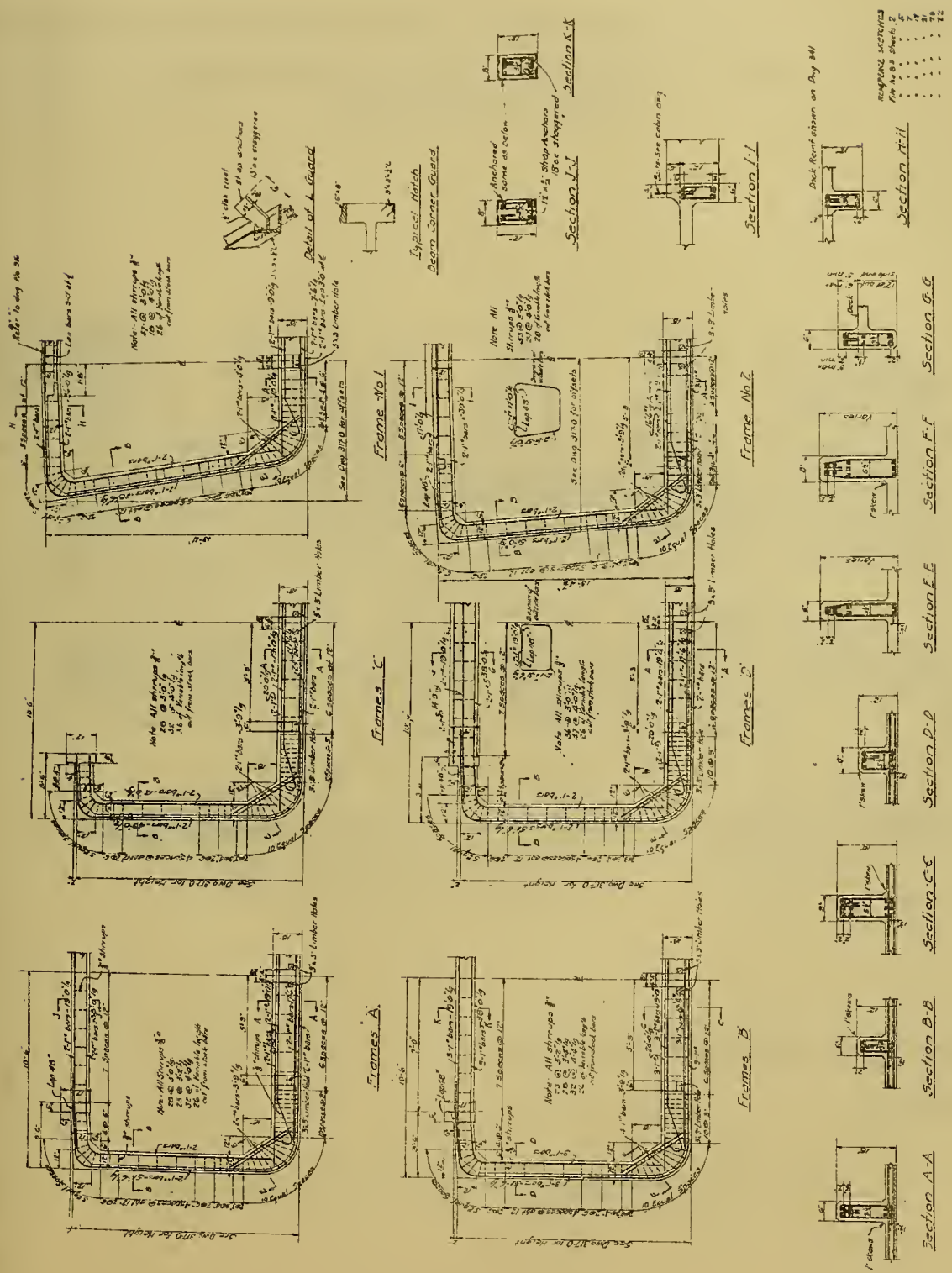
TRANSVERSE SECTION OF 2,500-TON CONCRETE SCHOONER RIGGED COAL BARGE.

THE NORRIS PETERS CO., WASH., D. C.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.


Plan
Longitudinal Section
Section AA
Section BB
Section CC
Section DD
Section EE
Section FF
Section GG
Section HH
Section KK
Section LL
Section MM
Section NN
Section OO
Section PP
Section QQ
Section RR
Section SS
Section TT
Section UU
Section VV
Section WW
Section XX
Section YY
Section ZZ

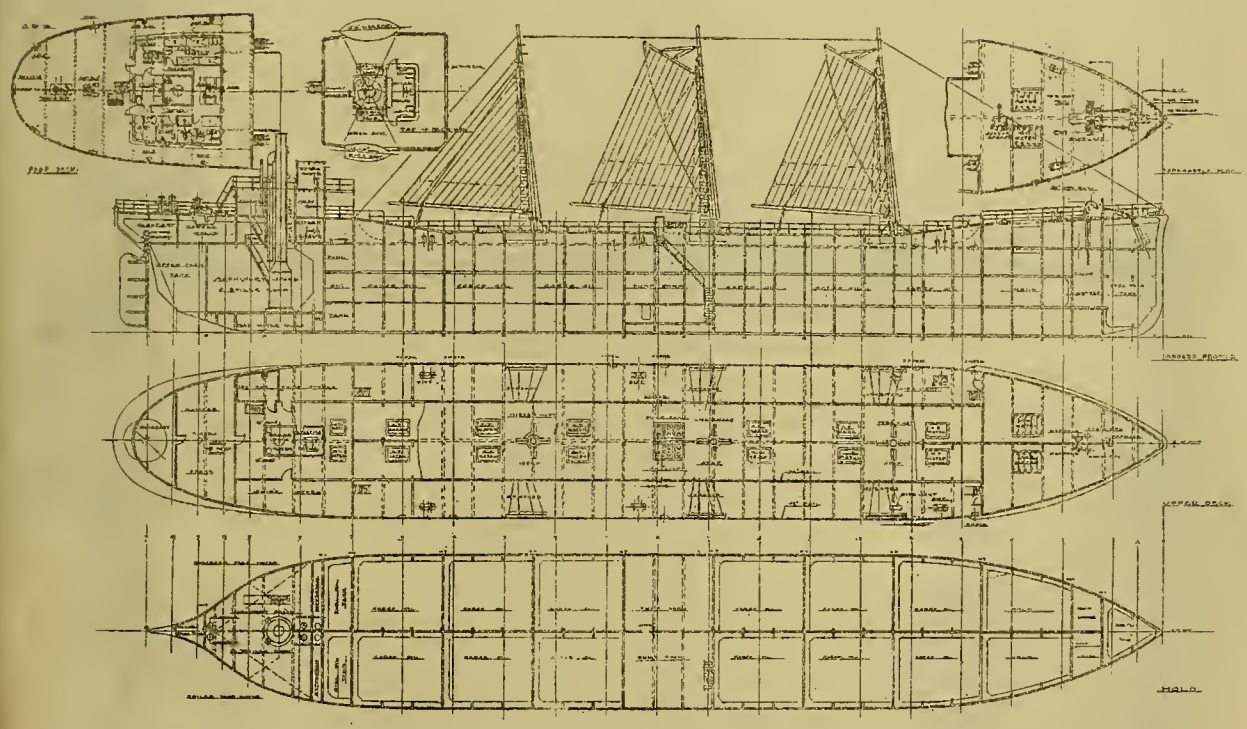
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



TYPICAL FRAMES 500-TON CONCRETE CANAL BARGE.

THE NORRIS PETERS CO., WASH., D. C.

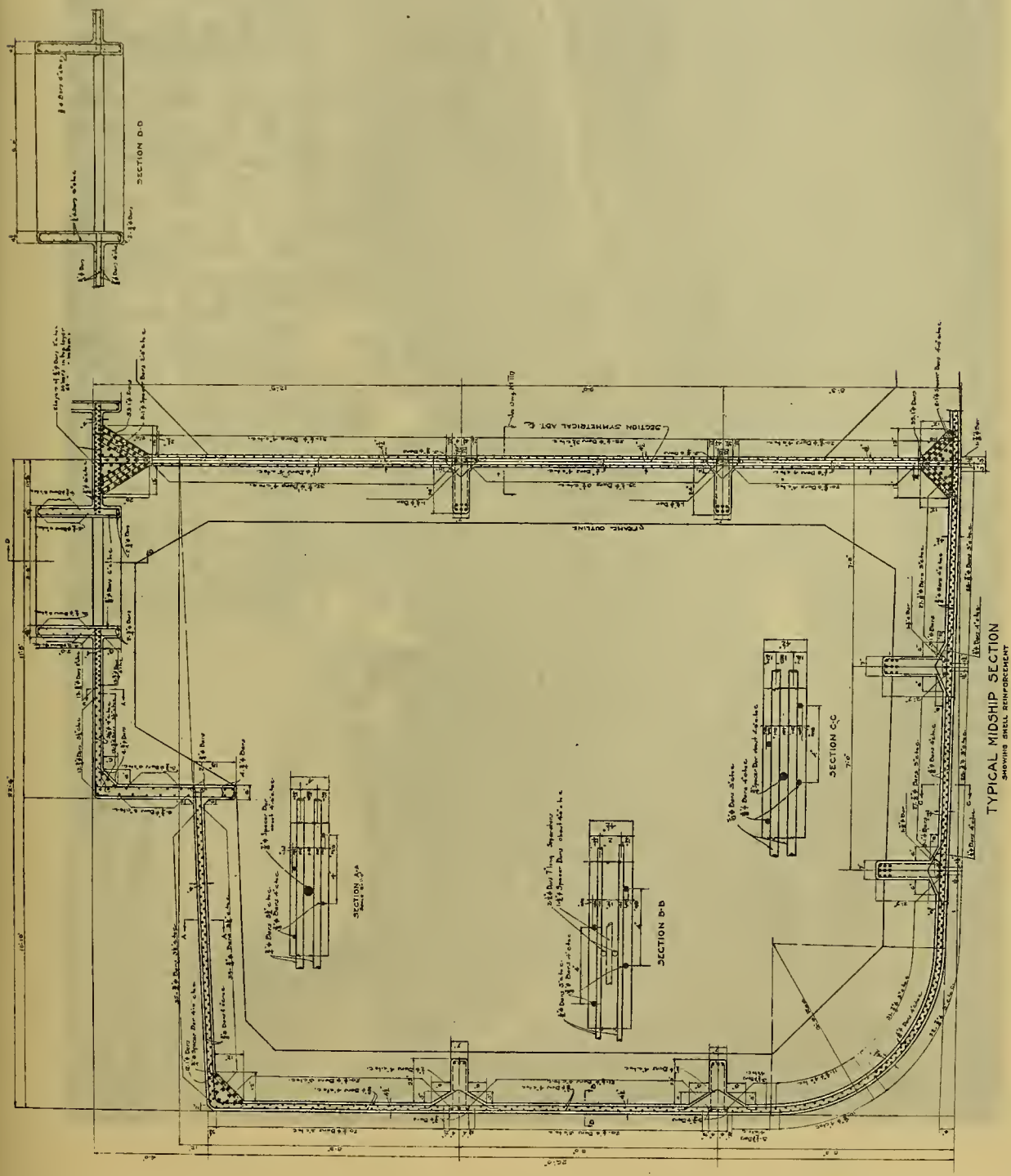
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



PROFILE OF 4,000-TON CONCRETE SCHOONER RIGGED COAL BARGE.

THE NORRIS PETERS CO., WASH D. C.

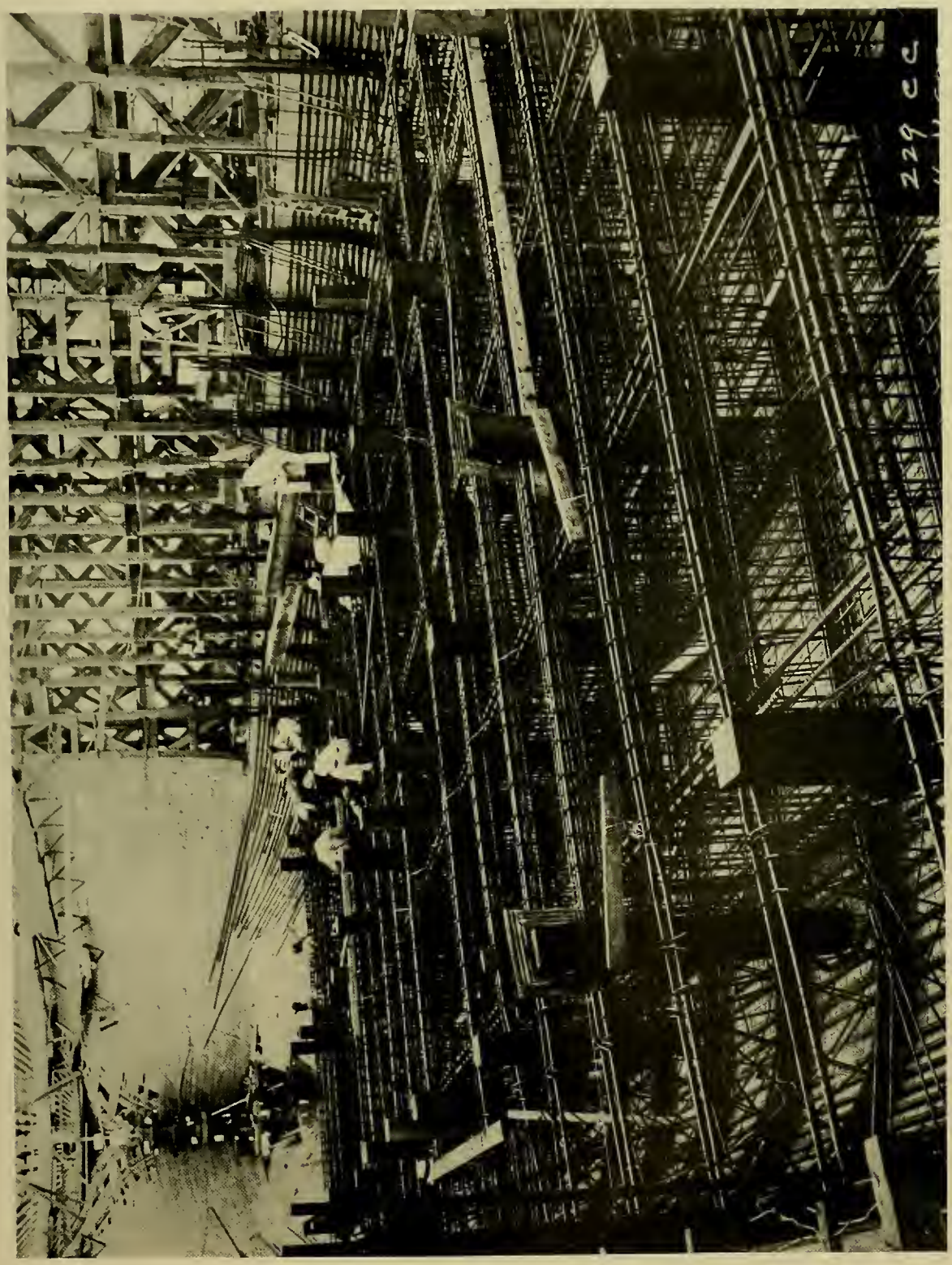
To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



TRANSVERSE SECTION OF 4,000-TON CONCRETE SCHOONER RIGGED COAL BARGE.

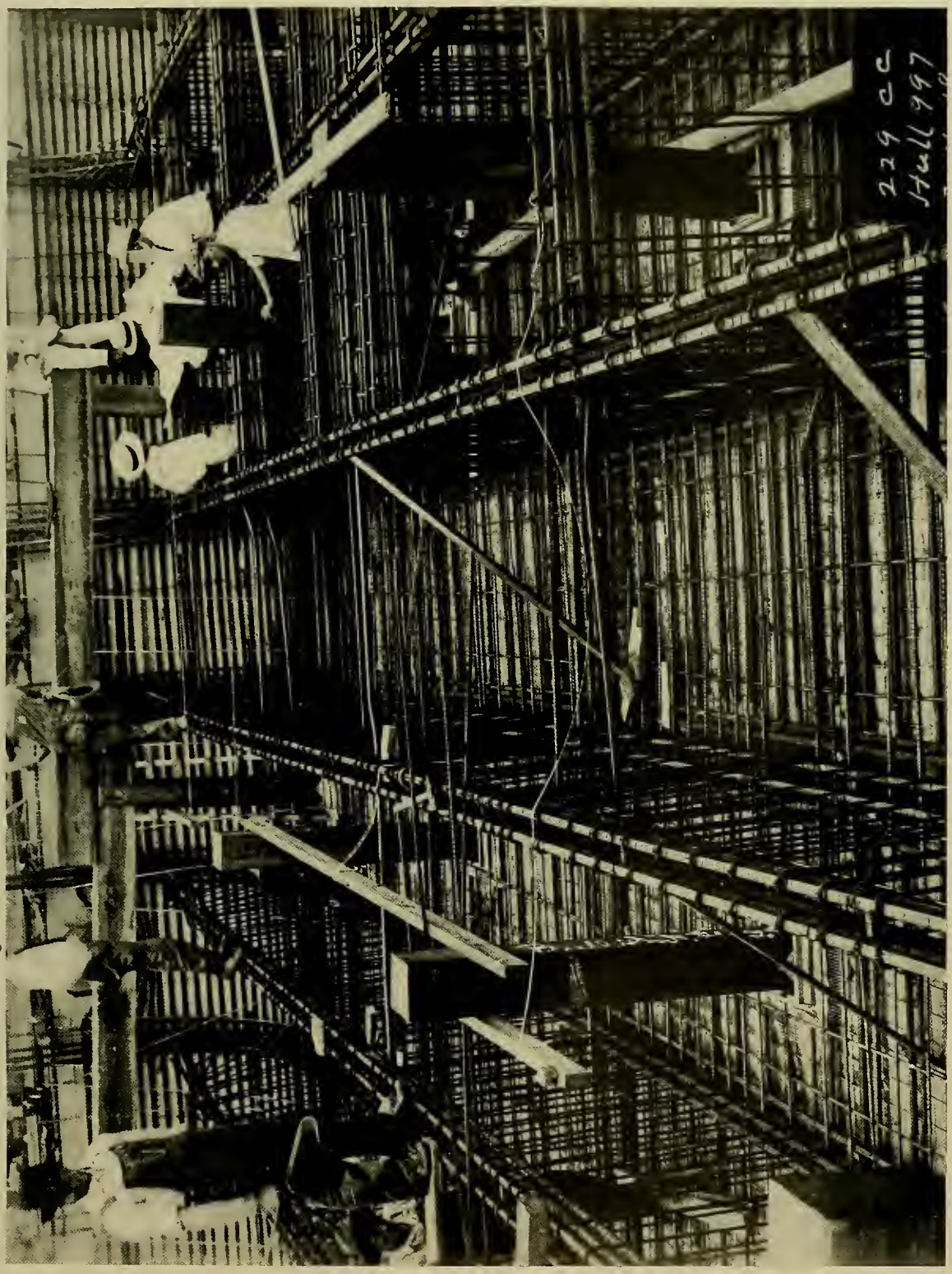
THE NORRIS PETERS CO., WASH., D. C.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



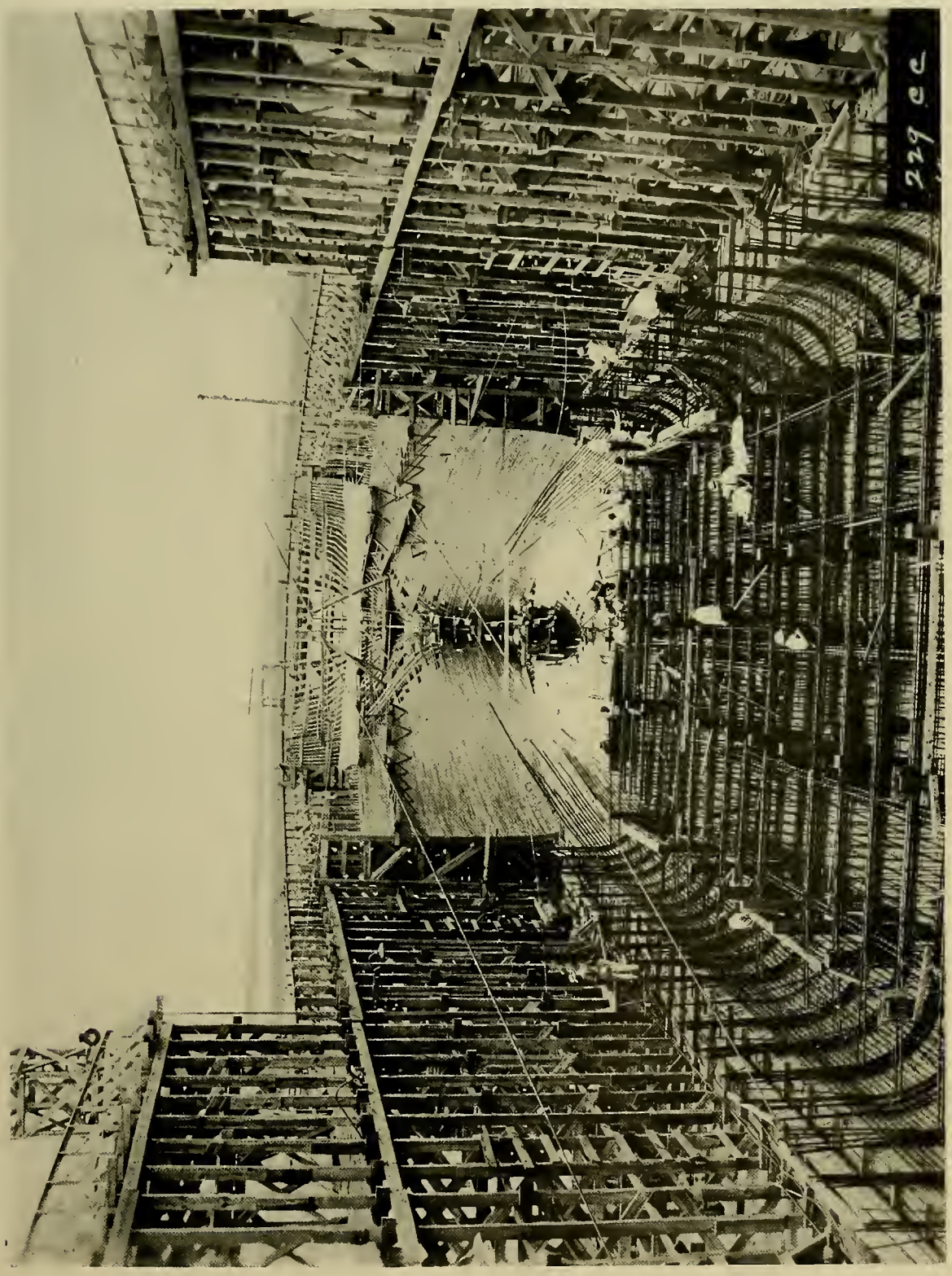
View Looking Aft from Starboard Side of 3,000-Ton Concrete Hull Under Construction at Brunswick, Ga., Showing Frame Steel Reinforcing in Position Through Midship Section.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



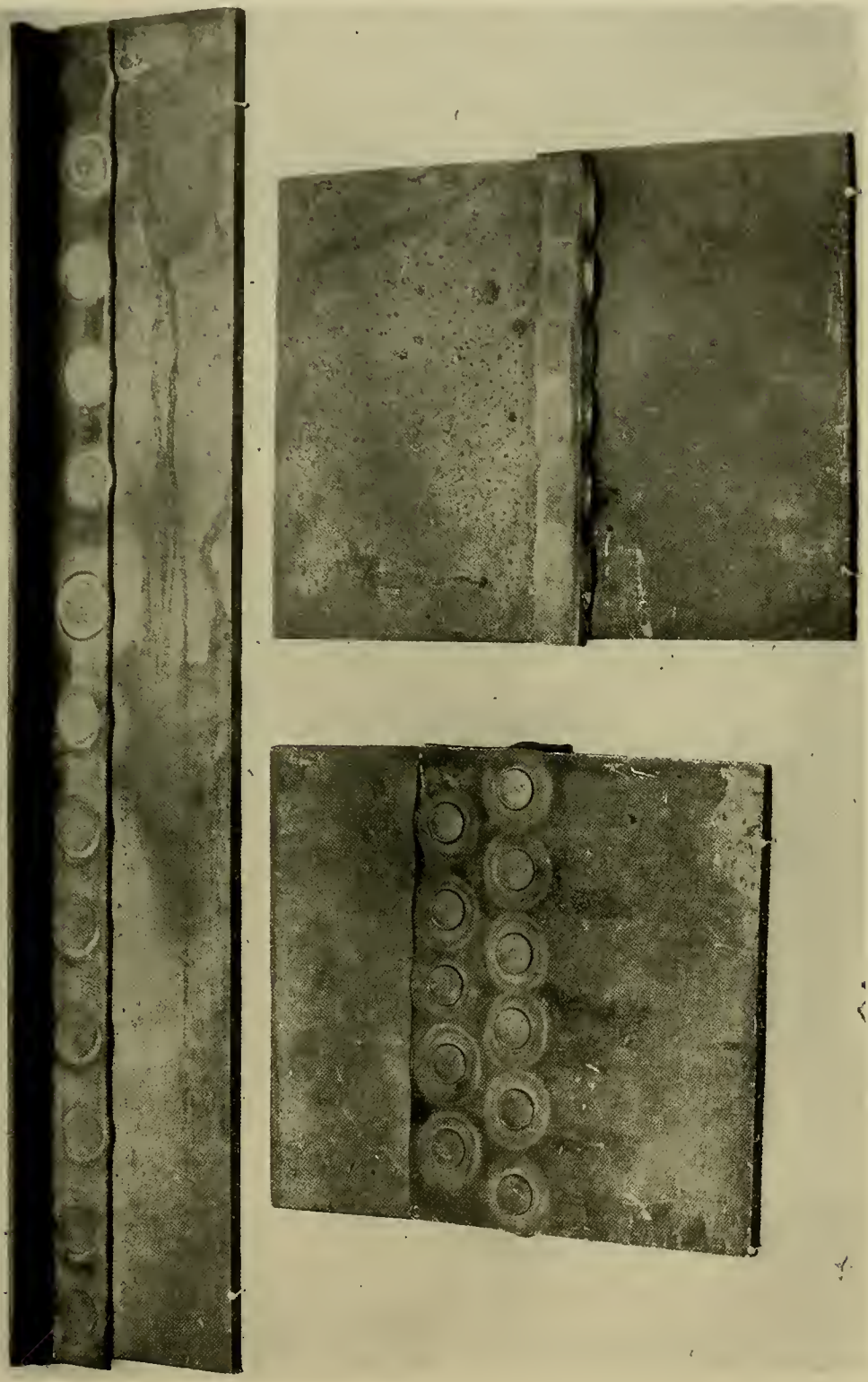
Steel Detail Athwart Midship Section. 3,000-Ton Concrete Ship Under Construction at Brunswick, Ga.

To illustrate paper on "Present Status of the Concrete Ship," by R. J. Wig, Esq., Visitor.



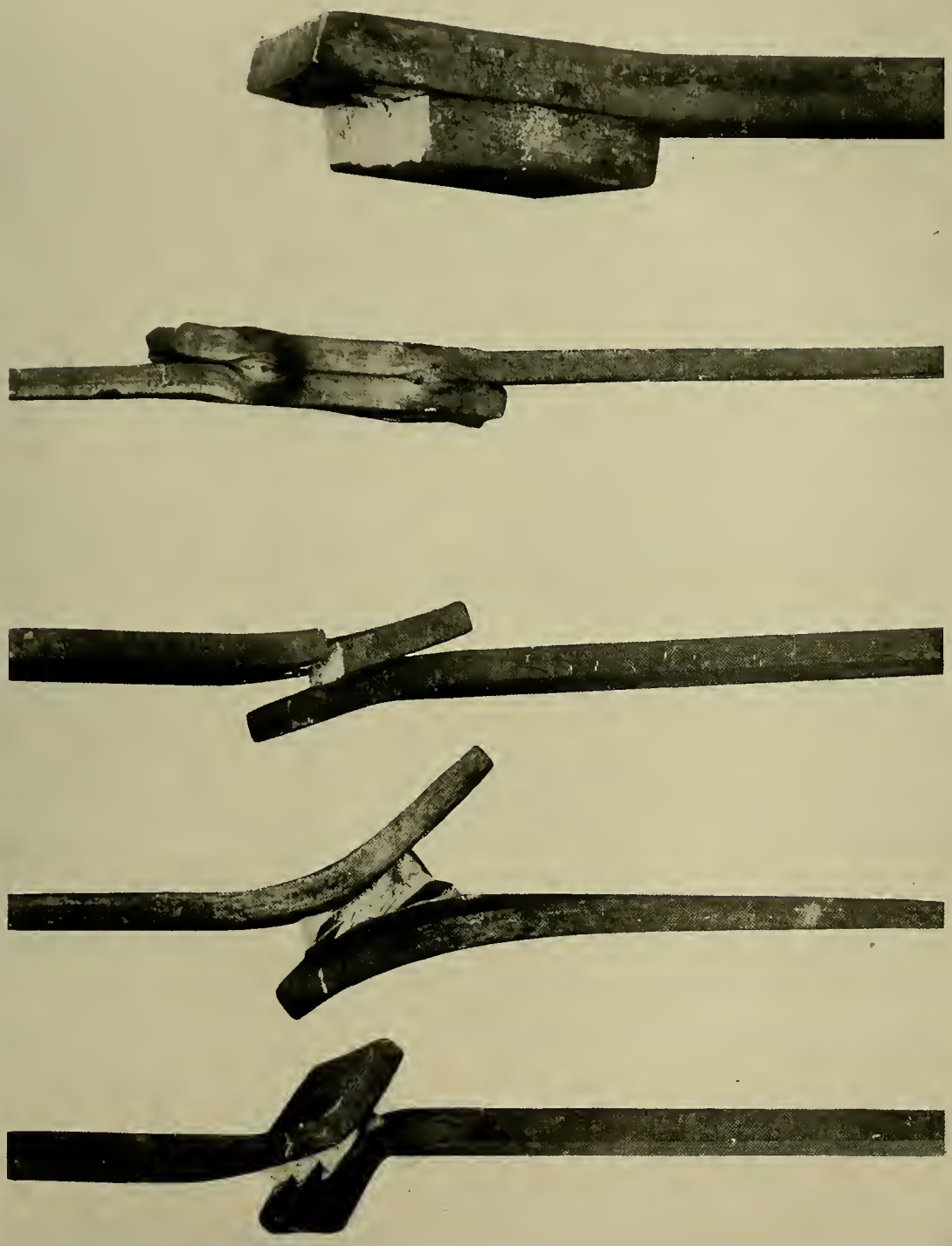
Inside View from Stern Showing Form Work and Steel Fabrication Partly in Place. 3,000-Ton Concrete Ship Under Construction at Brunswick, Ga.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



SPECIMENS OF SPOT WELDED ATTACHMENTS MADE BY THE GENERAL ELECTRIC COMPANY.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



General Electric Company's Spot Welding Tests.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.

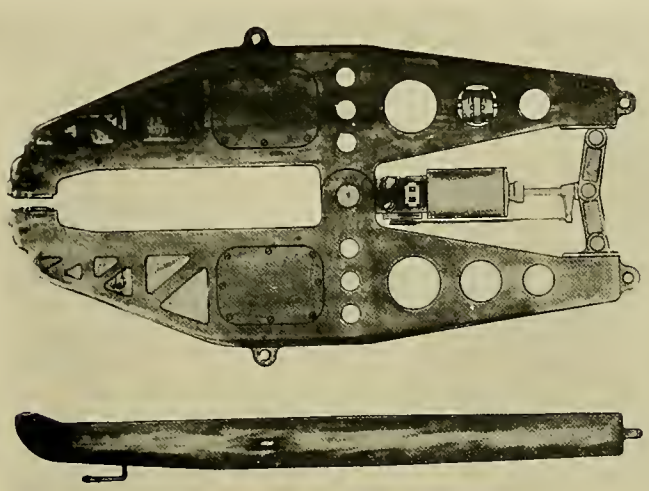


Fig. 1.—Gap Portable Spot Welder.

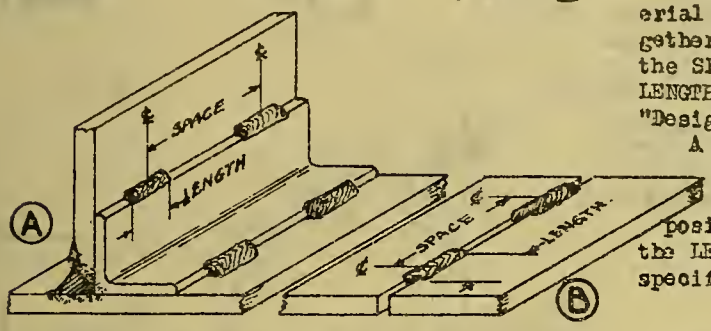
Fig. 2.—Half of Double V in ½-Inch Ship Plates, Automatically Welded at the Rate of 15 Feet Per Hour.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.

KIND · OF · WELD

TACK

SYMBOL · 6 ·

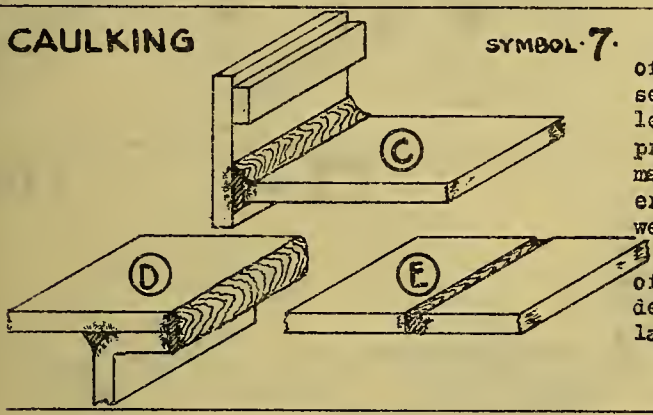


A TACK weld is applying the welding material in small sections to hold two edges together, and should always be specified by giving the SPACE from center to center of weld and the LENGTH of the weld itself. No particular "Design of weld" is necessary of consideration.

A TACK is also used for temporarily holding material in place that is to be solidly welded, until the proper alignment and position is obtained, and in this case, neither the LENGTH, SPACE, or DESIGN OF WELD are to be specified.

CAULKING

SYMBOL · 7 ·

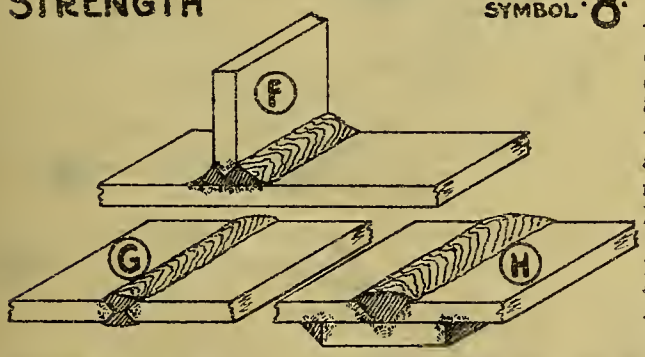


A CAULKING weld is one in which the density of the crystaline metal, used to close up the seam or opening, is such, that no possible leakage is visible under a water, oil or air pressure of 25 lbs. per square inch. The ultimate strength of a caulking weld is not of material importance,- neither is the "Design of weld" of this kind necessary of consideration.

The operator must be the judge in the number of layers needed for a tight weld, although the designer should specify a minimum amount of layers.

STRENGTH

SYMBOL · 8 ·

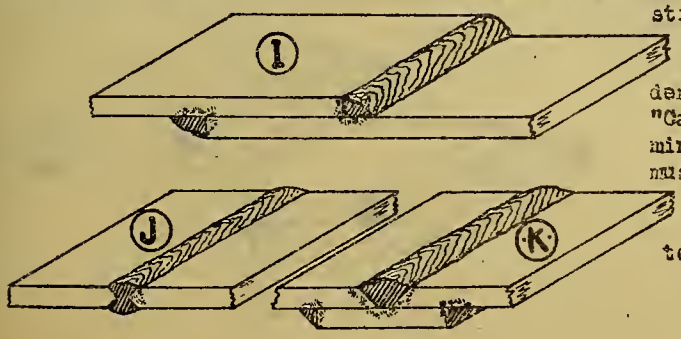


A STRENGTH weld is one in which the sectional area of the welding material must be so considered that its tensile strength and elongation per square inch must be equal at least 80% of the ultimate strength per square inch of the surrounding material. (To be determined and specified by the designer). The welding material can be applied in any number of layers beyond a minimum specified by the designer.

The density of the crystaline metals is NOT of vital importance. In this form of weld, the "Design of weld" must be specified by the designer and followed by the operator.

COMPOSITE

SYMBOL · 9 ·



A COMPOSITE weld is one in which both the strength and density are of the most vital importance. The STRENGTH must be at least as specified for a "strength weld", and the density must meet the requirements of a "Caulking weld" both as above defined. The minimum number of layers of welding material must always be specified by the designer, but the welder must be in a position to know if this number must be increased according to the welders working conditions.

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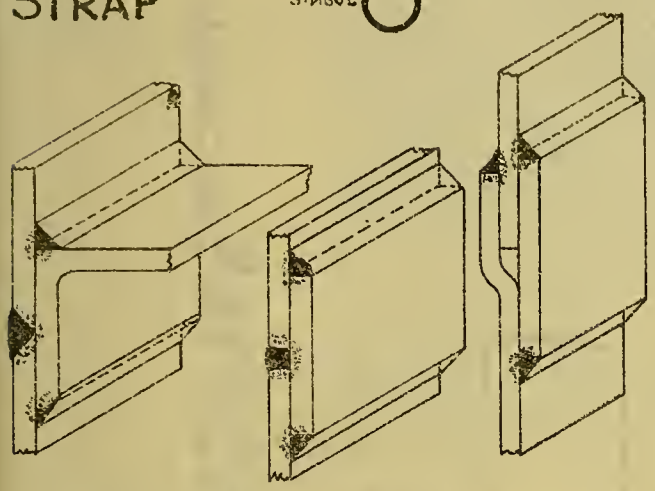
TYPE OF JOINT

STRAP

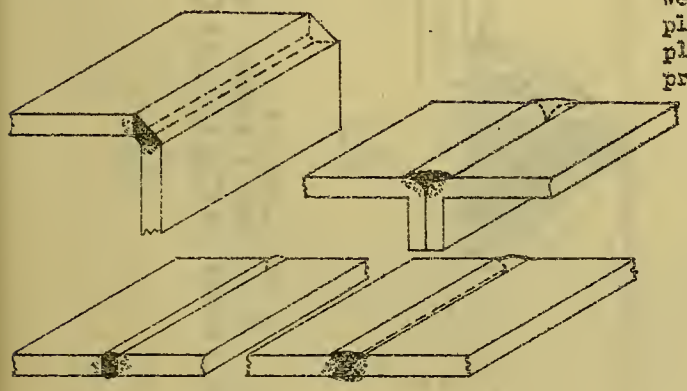
SYMBOL ○



STRAP weld is one in which the seam of two adjoining plates or surfaces is reinforced by any form or shape to add strength and stability to the joint or plate. In this form of weld the seam can only be welded from the side of the work opposite the reinforcement, and the reinforcement of whatever shape must be welded from the side of the work to which the reinforcement is applied.

BUTT

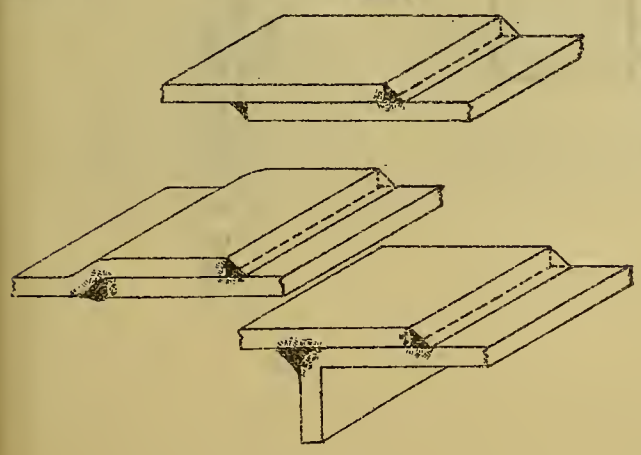
SYMBOL □



BUTT weld is one in which two plates or surfaces are brought together edge to edge and welded along the seam thus formed. The two plates when so welded, form a perfectly flat plane in themselves excluding the possible projective caused by other individual objects as frames, straps, stiffeners, etc., or the building up of the weld proper.

LAP

SYMBOL △



LAP weld is one in which the edges of two plates are set one above the other and the welding material so applied as to bind the edge of one plate to the face of the other plate. In this form of weld the seam or lap forms a raised surface along its entire extent.

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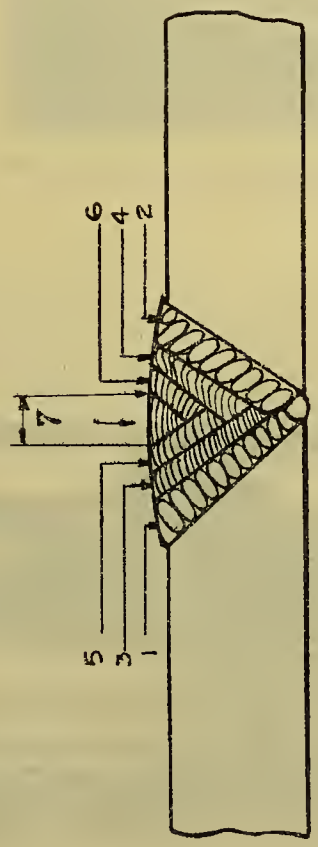
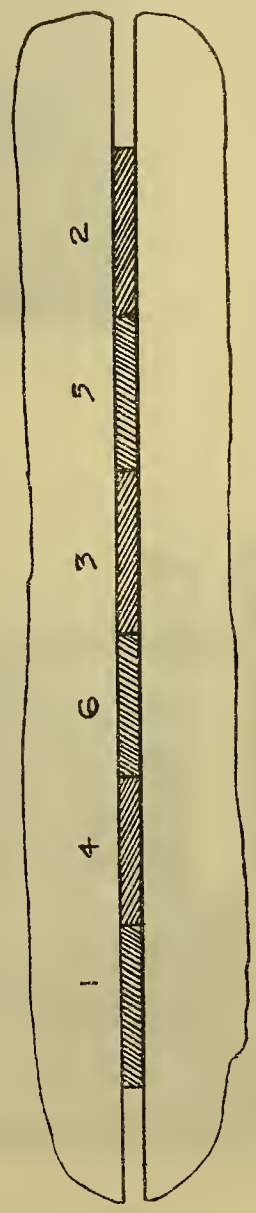
METHOD OF APPLYING METAL TO ELECTRIC WELDED JOINTS IN LAYERS SAY 6" TO 12" LONG AS PROPOSED BY NAVAL CONSTR. H. G. KNOX.



NOTE THE FINAL LAYER No 7 IS SO REDUCED AS TO HAVE LITTLE HEAT EFFECT.



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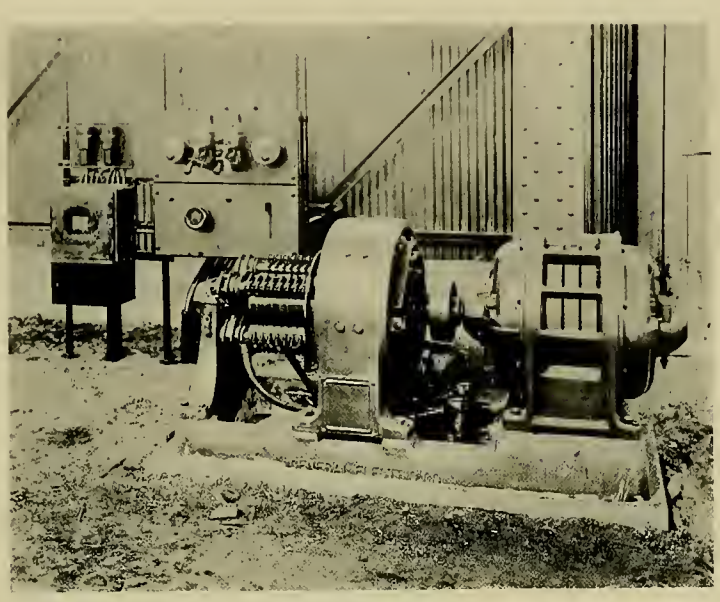

Fig 1.—Four-Arc D. C. Motor Generator Set. Manufactured by The General Electric Co.

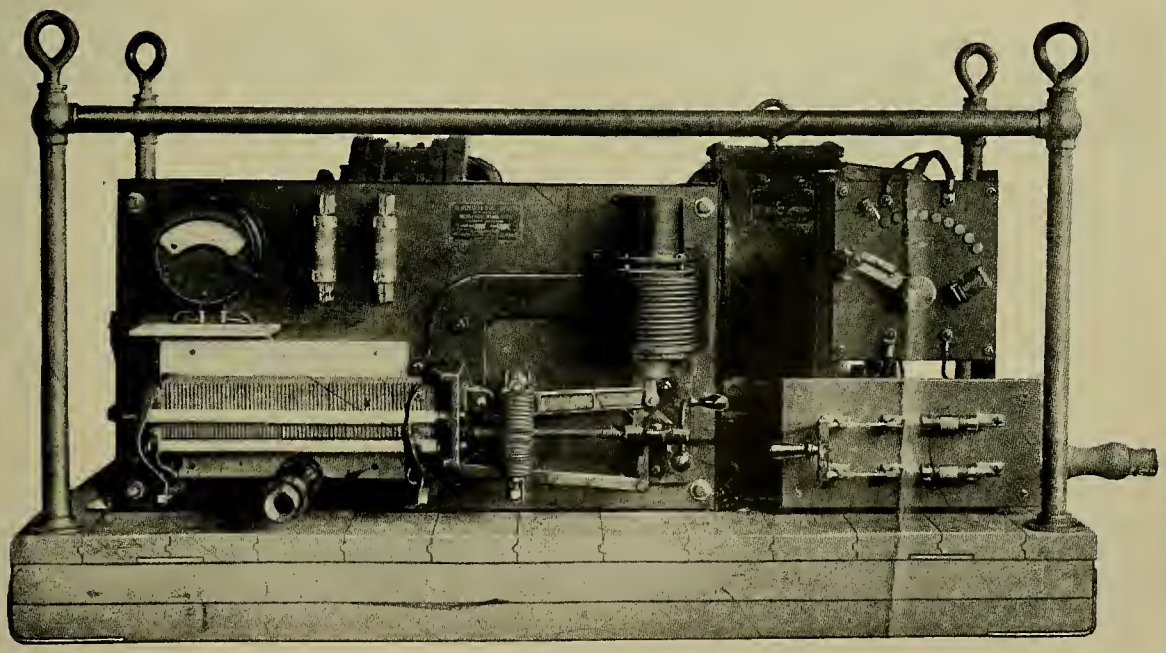

Fig. 2.—"Naval" Type One-Arc D. C. Motor Generator Set. Manufactured by The Wilson Welding and Metals Co.

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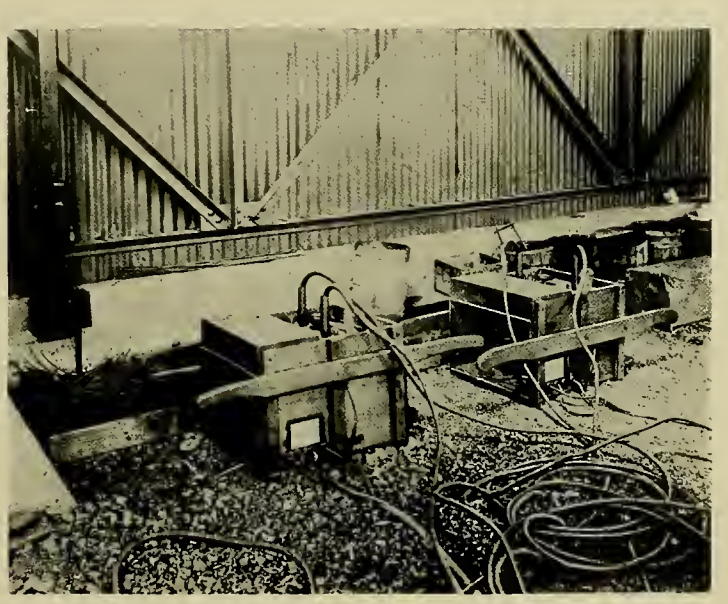
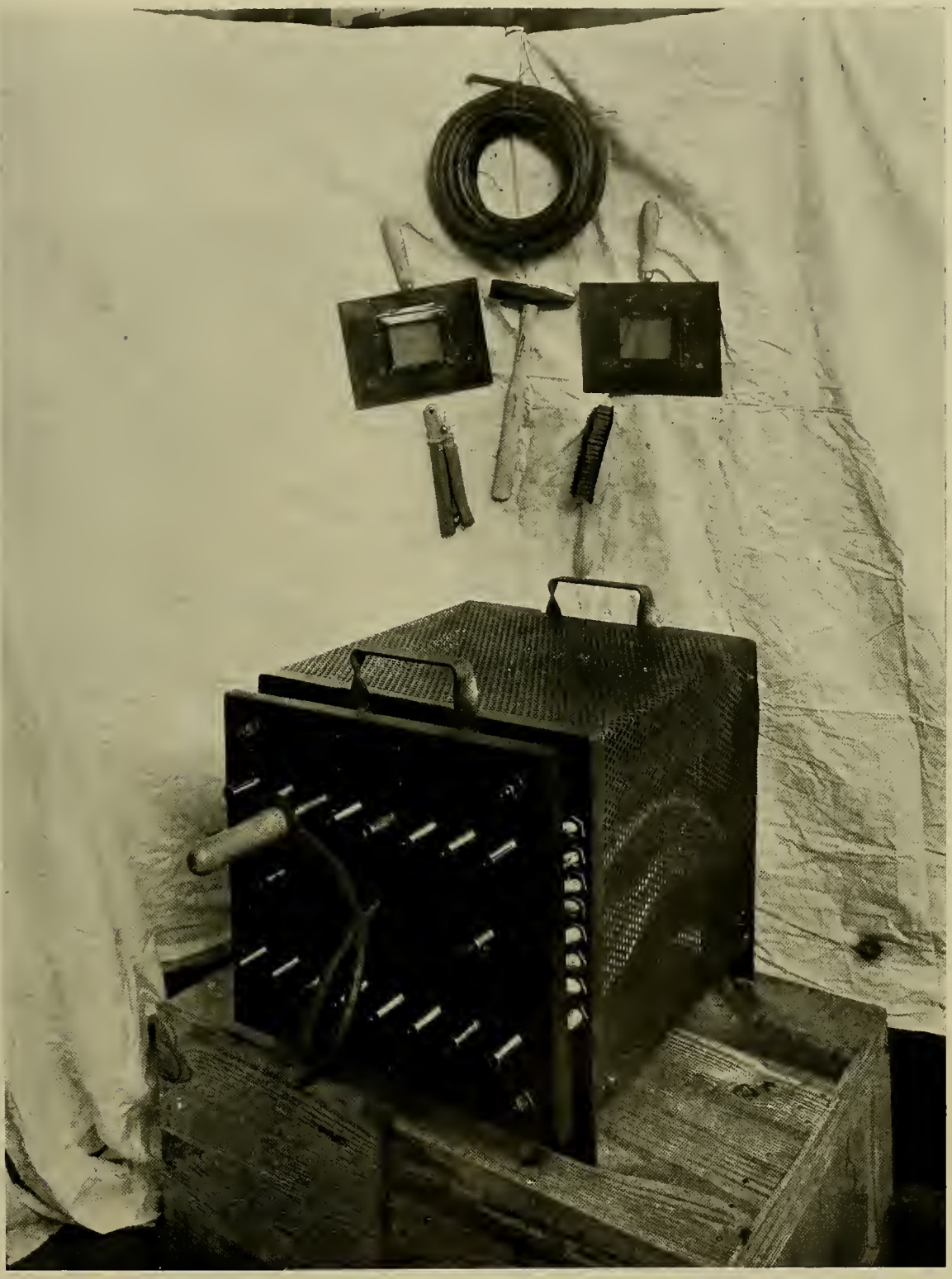


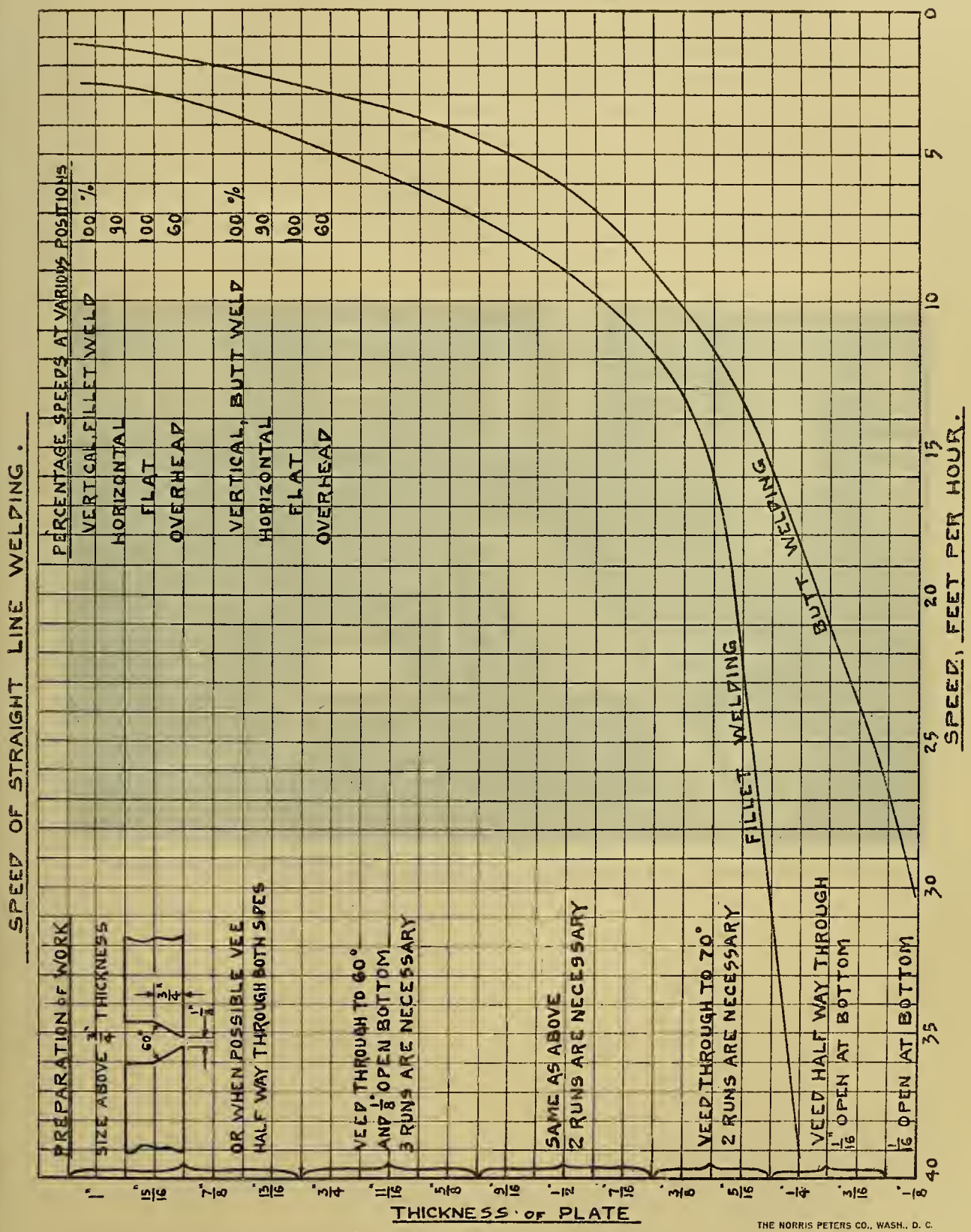
One-Arc A. C. Stationary Transformer. Manufactured by The Electric Arc Cutting and Welding Co.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



Electric Arc Welding Equipment, Supplied by the Quasi Arc Weltrode Co.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



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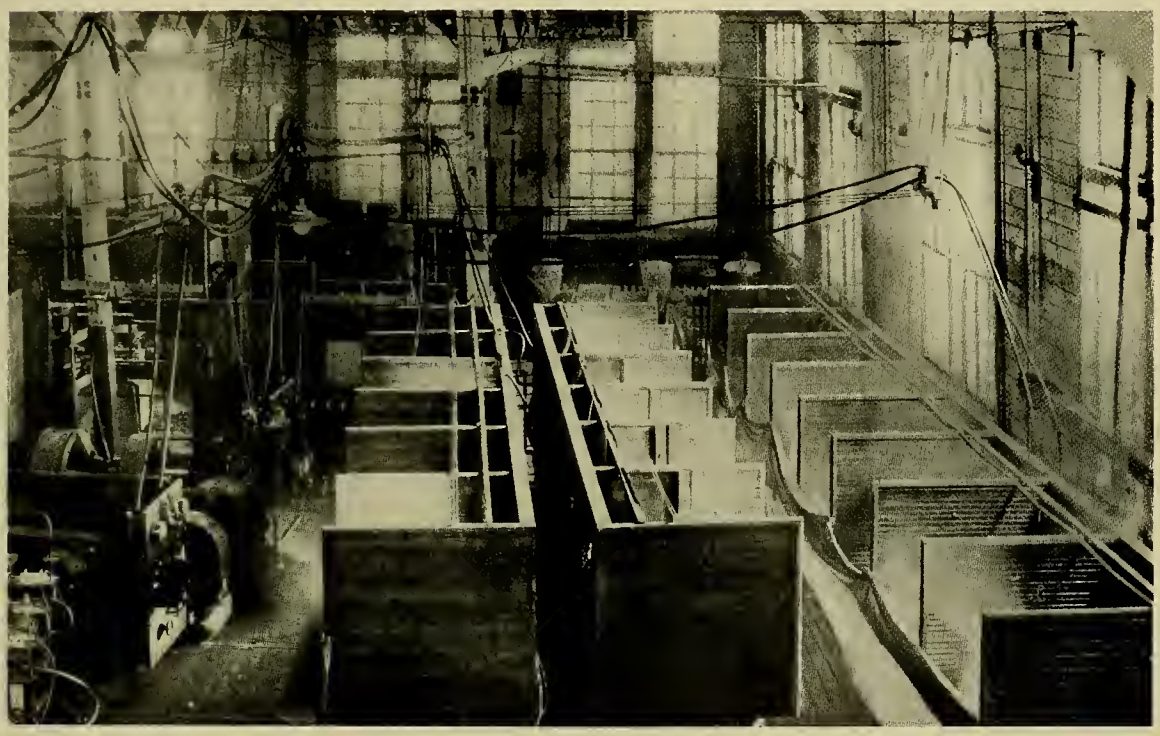
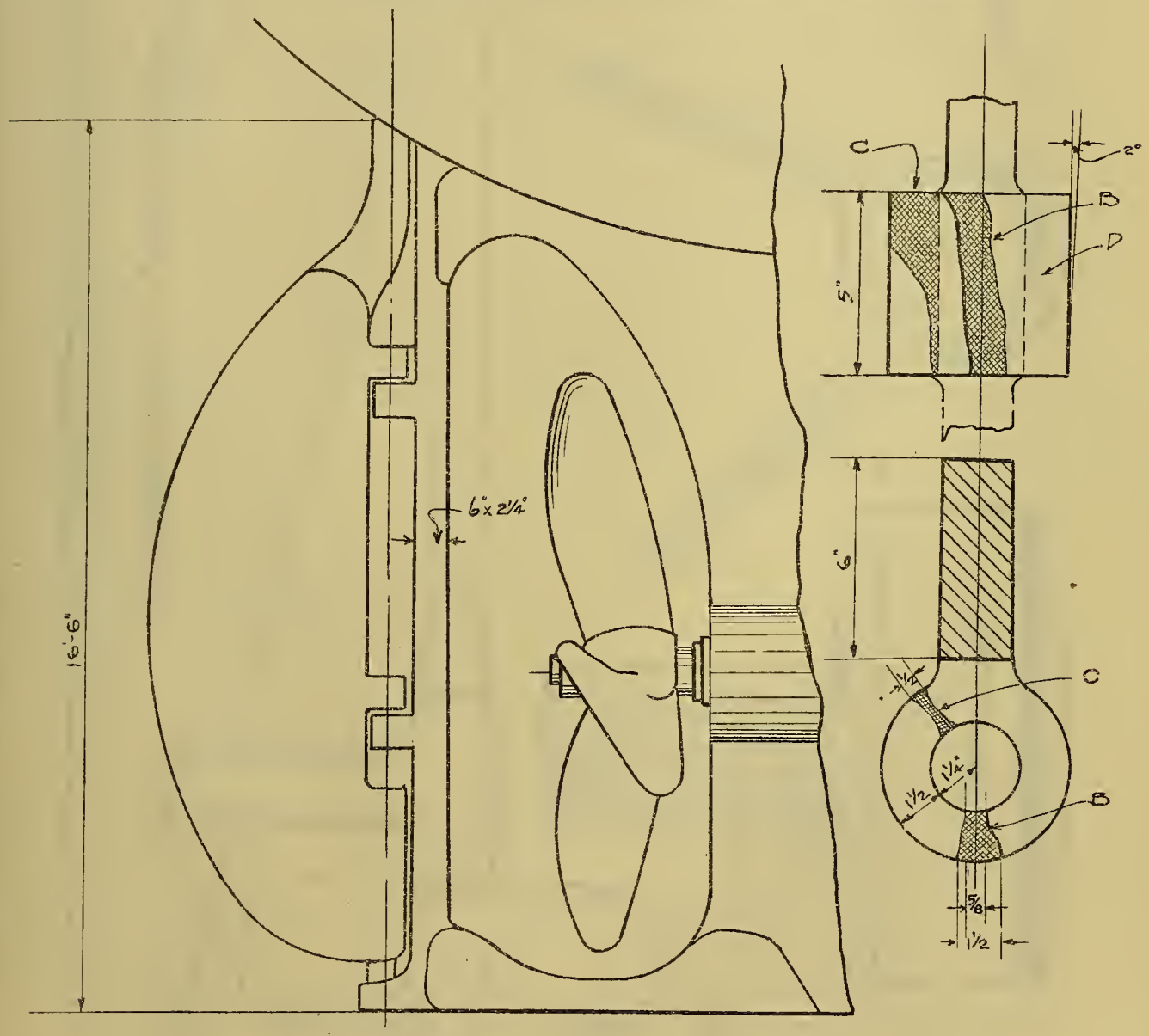
To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



School for Electric Arc Welders Established by the Emergency Fleet Corporation at the Plant of The General Electric Company, Schenectady, N. Y.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.

REPAIR TO STERN POST GUDGEON.



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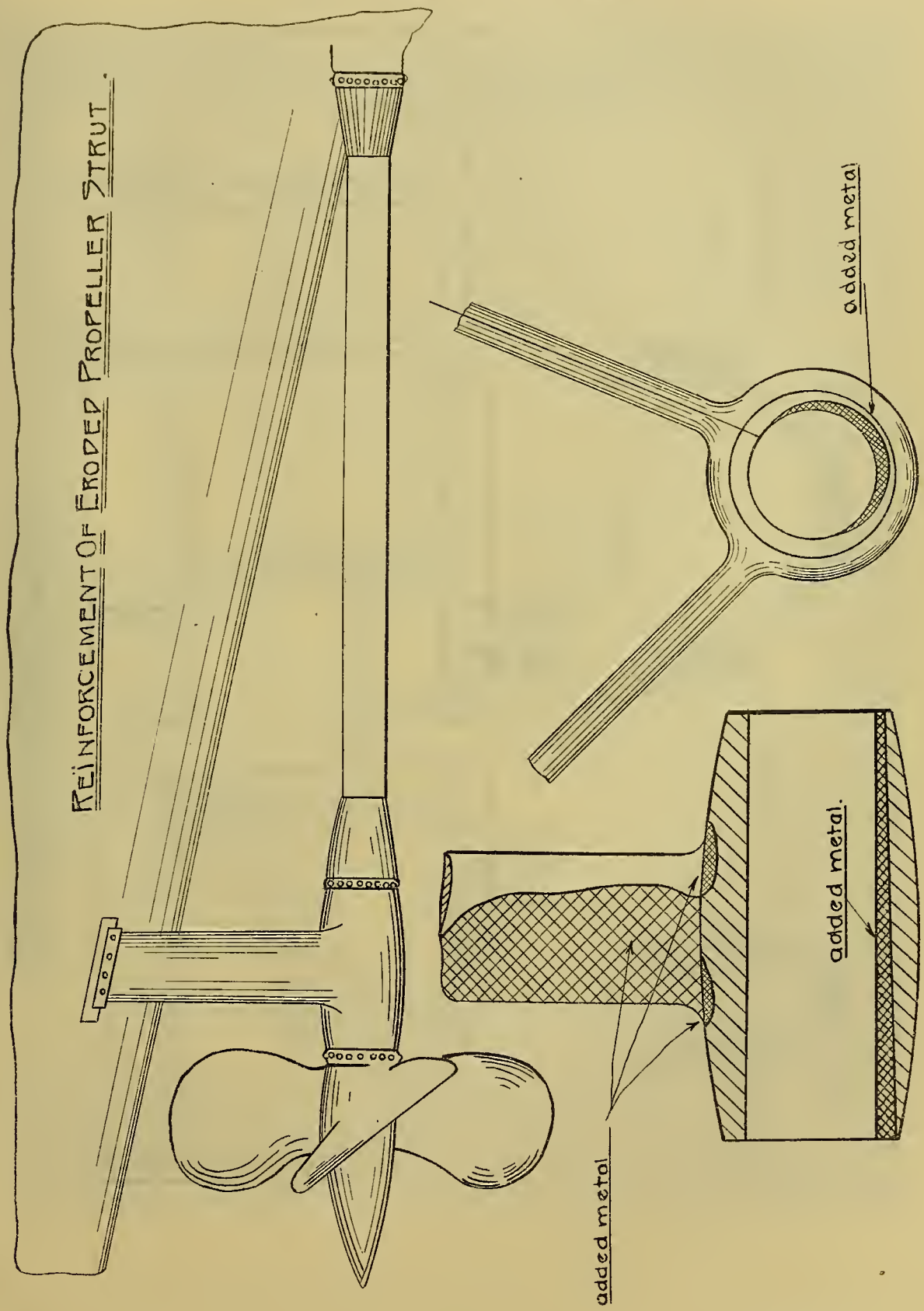

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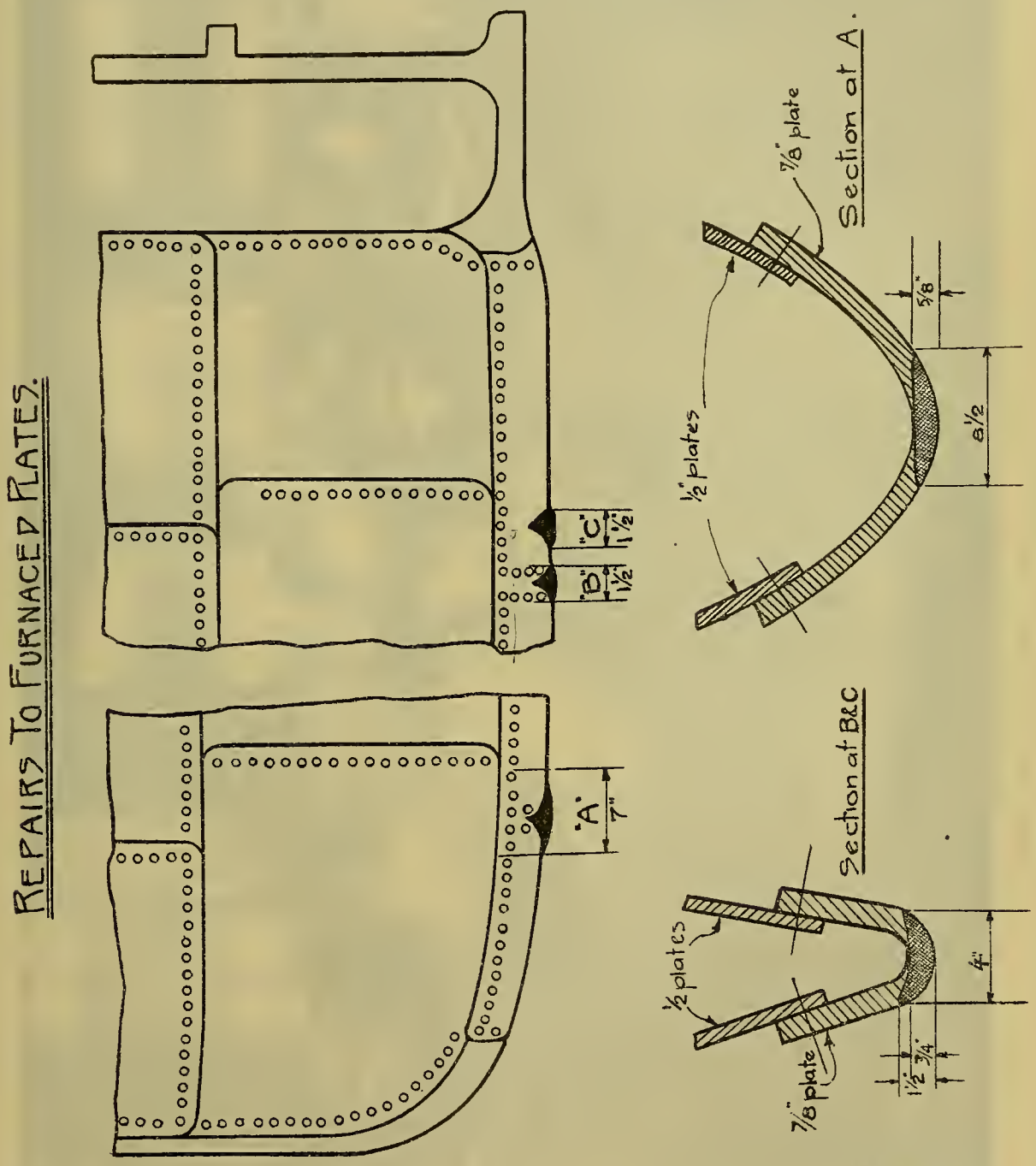

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Electric Arc Welding Shop at the Submarine Boat Corporation Plant.

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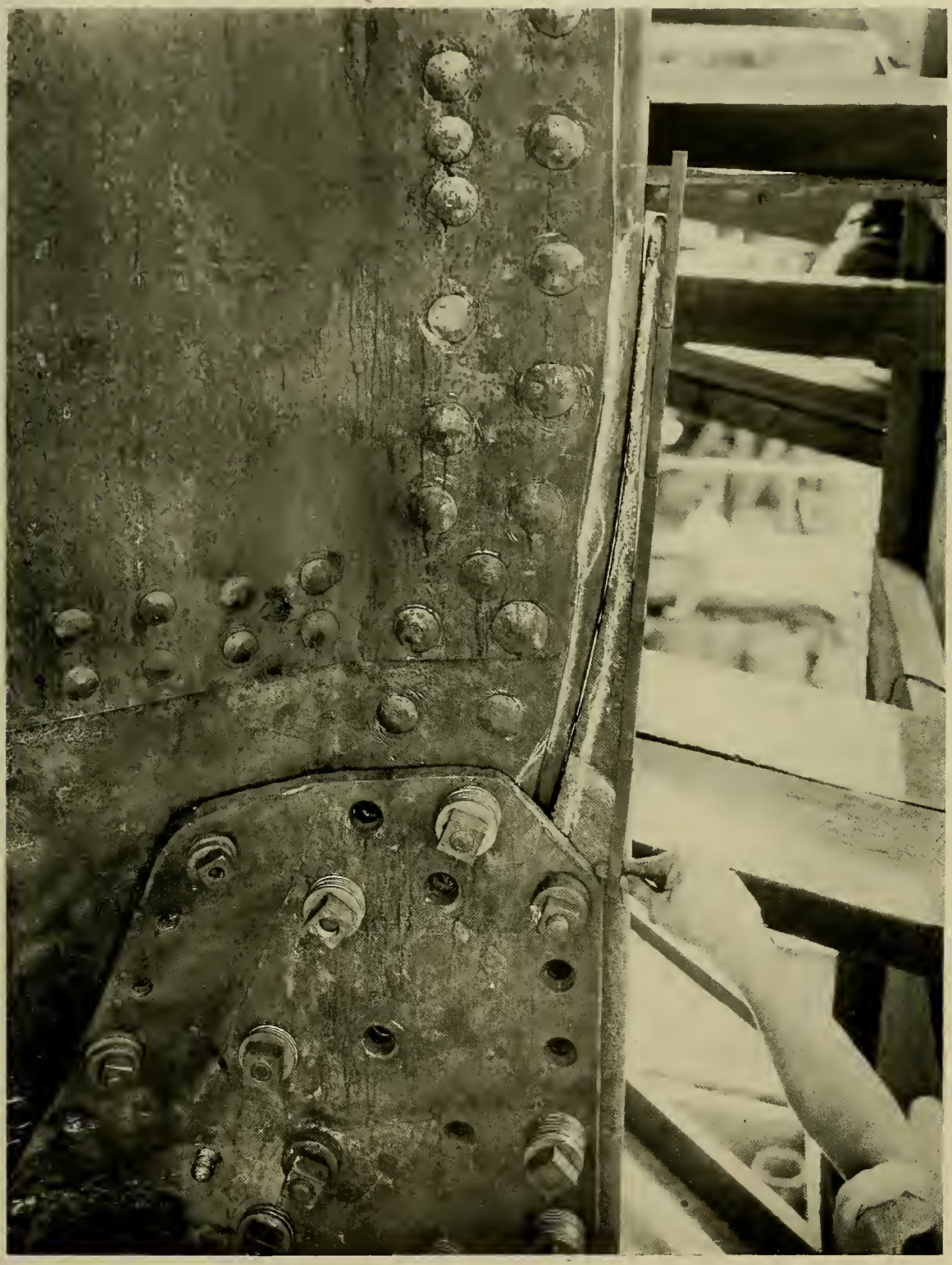
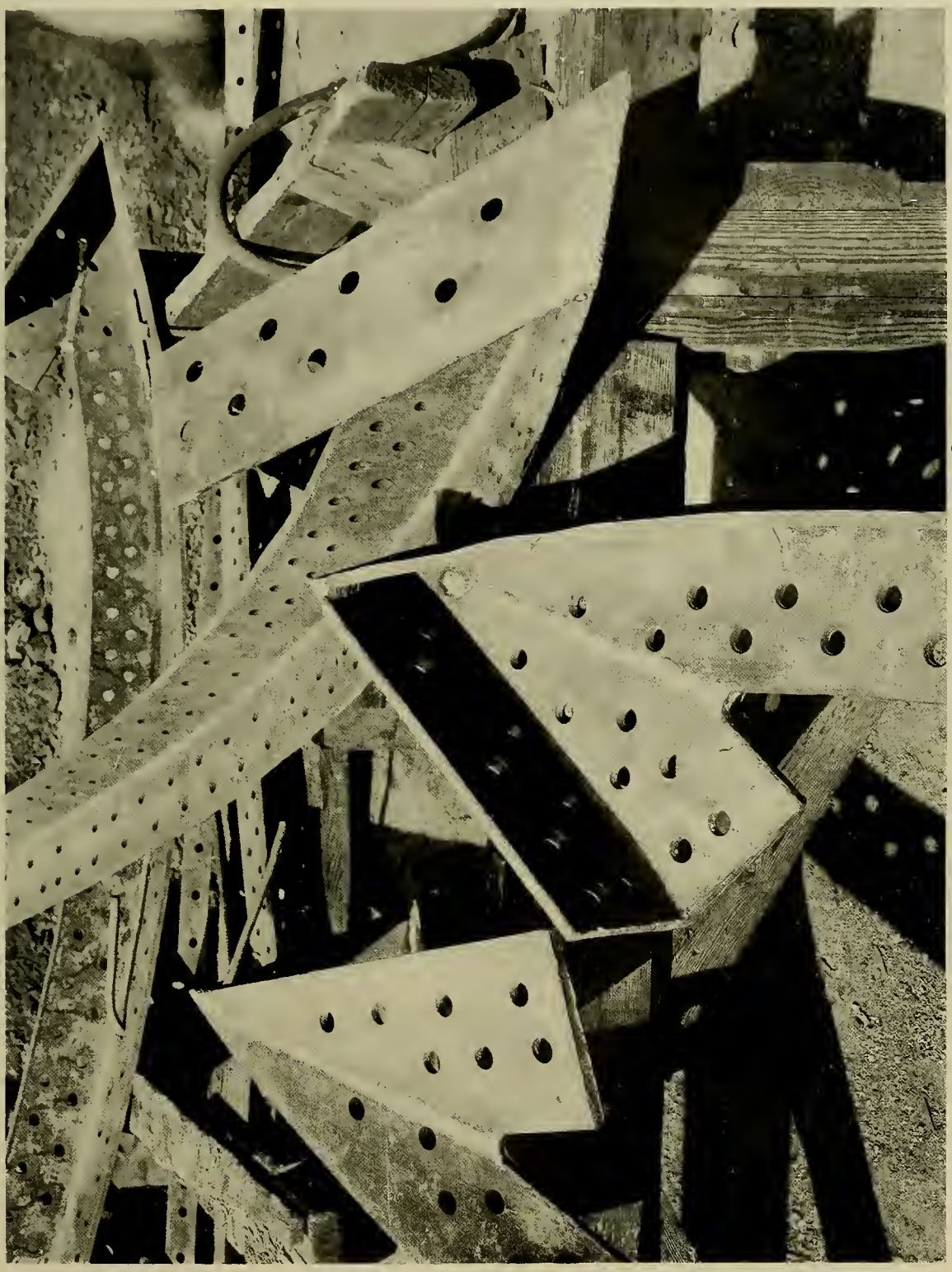


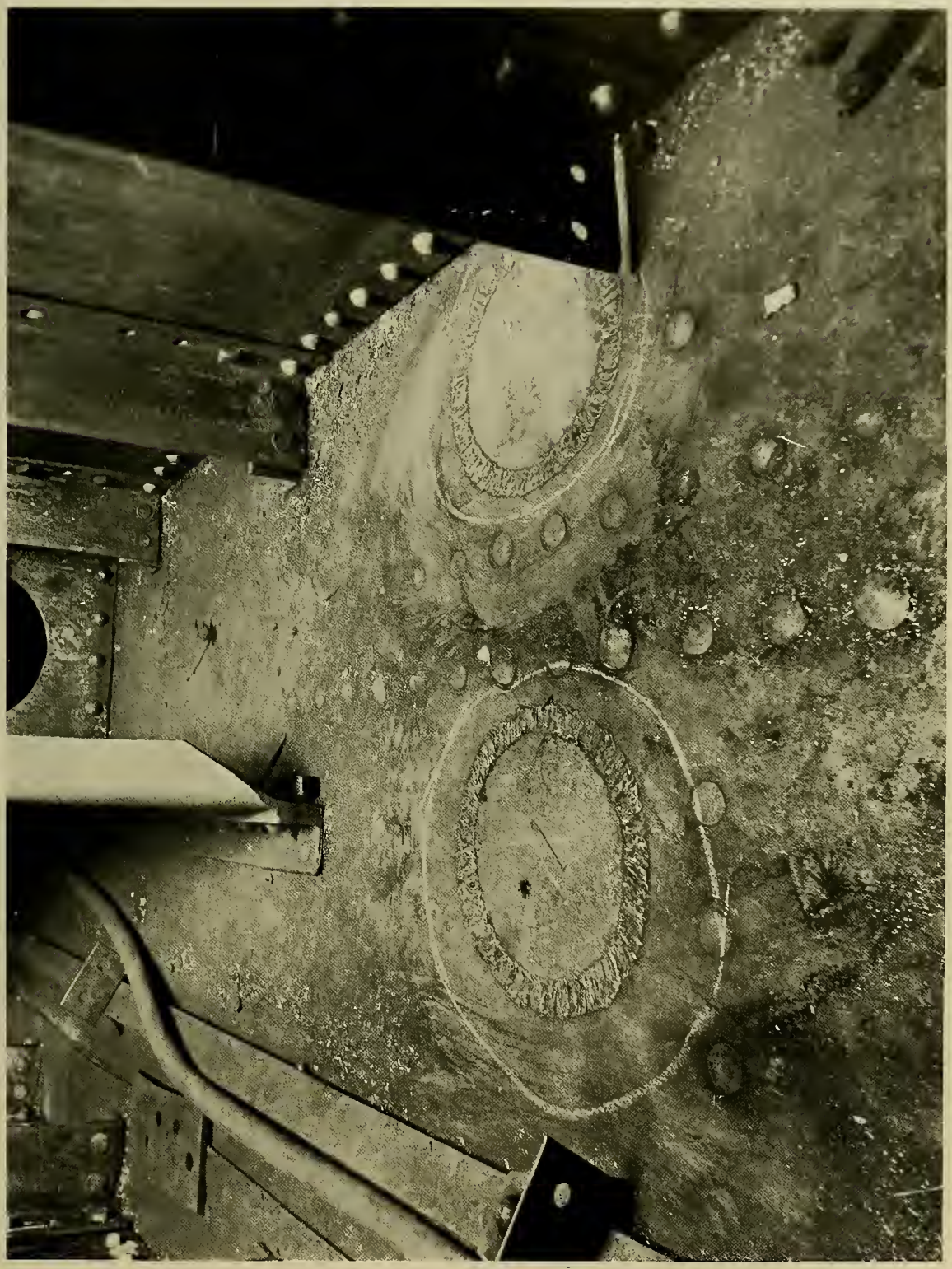
ATTACHMENT OF OTTER EXTENSION TO STEM.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



Elimination of Angle Smith Work in W. T. Floor Boundary Angles.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



Misplaced Pipe Holes in Inner Bottom Plating, Welded in 3½ Hours, Using 3 Pounds of Bare Electrode.

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.

Fig. 1.—Lloyd's Register Experiments. Static Tensile Tests.

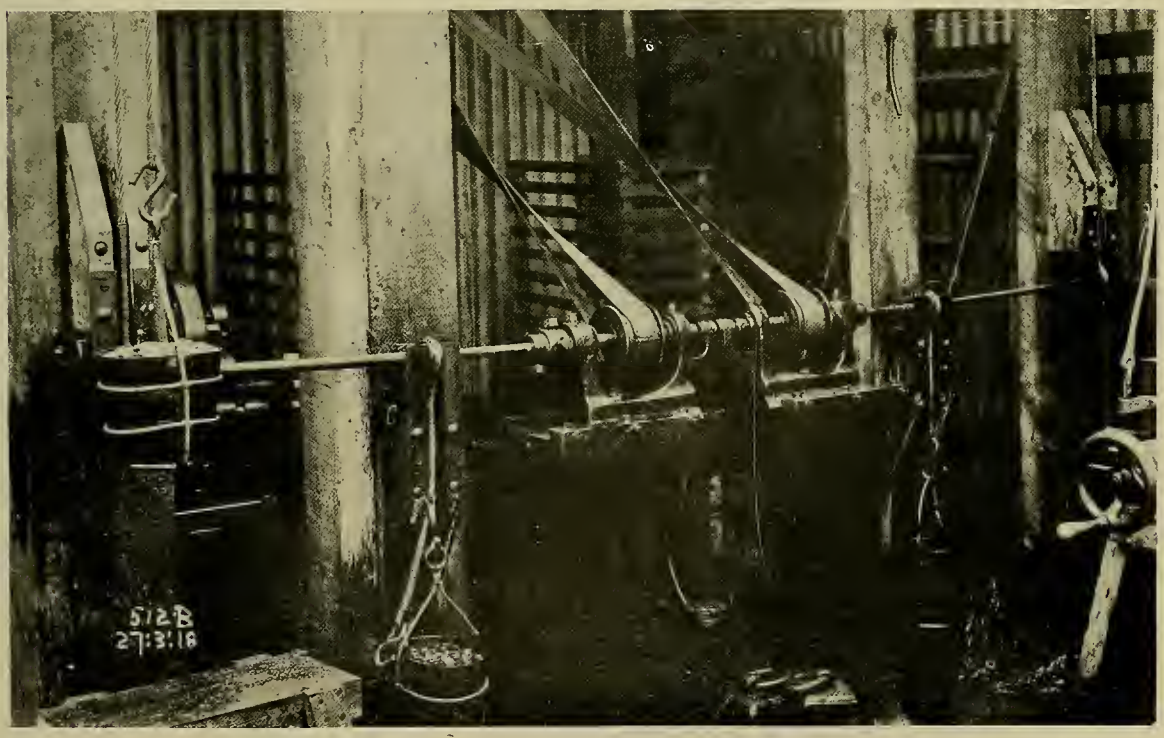


Fig. 2.—Lloyd's Register Experiments. Machine Used for Rotating Alternating Stress Tests.

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— LLOYDS EXPERIMENTS. —

STRAINMETER READINGS.

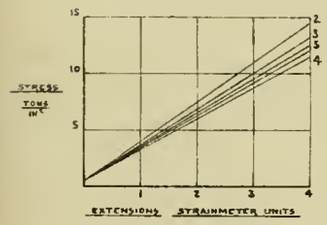
3/4" PLATE with TRANSVERSE BUTT WELD.

POSITIONS OF READINGS

— FIG. 1 —

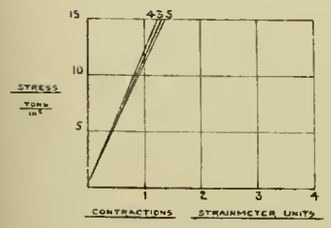
EXTENSIONS IN DIRECTION OF PULL

READING ALONG LINE C



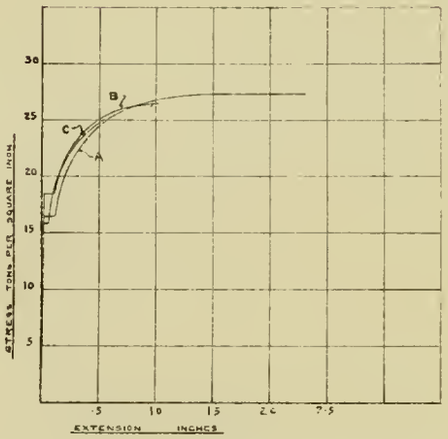
— FIG. 2 —

CONTRACTIONS AT 90° TO AXIS OF PULL

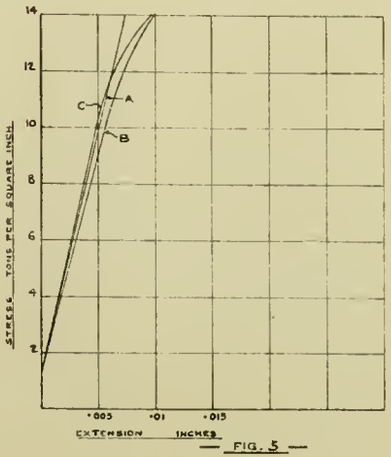


— FIG 3 —

STRESS—STRAIN DIAGRAMS FOR SMALL TEST PIECES.



— FIG. 4 —



— FIG. 5 —

ALTERNATING STRESS TESTS

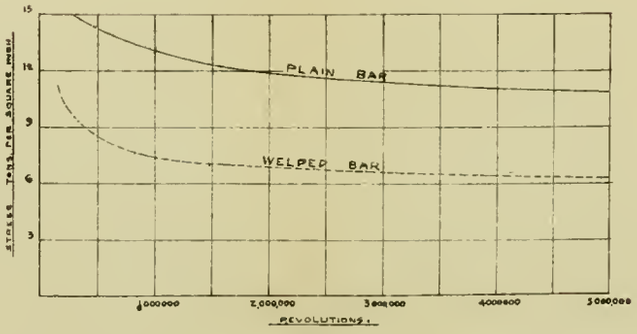
ROTATING BARS.

DIAGRAMMATIC VIEW OF APPARATUS.

THIS END OF BAR FREE BUT SUPPORTED BY UPWARD PULL W

END FIXED IN LATHE WHICH REVOLVES AT 1060 REV/MIN.

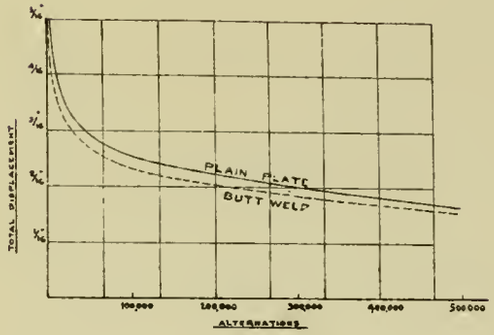
W=W UPWARD = DOWNWARD
BENDING MOMENT BETWEEN B AND C IS UNIFORM AND EQUAL TO Wa2



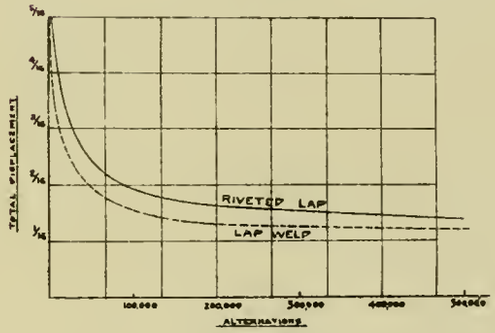
— FIG. 6 —

ALTERNATING STRESS TESTS

STATIONARY TEST PIECES FLAT BARS

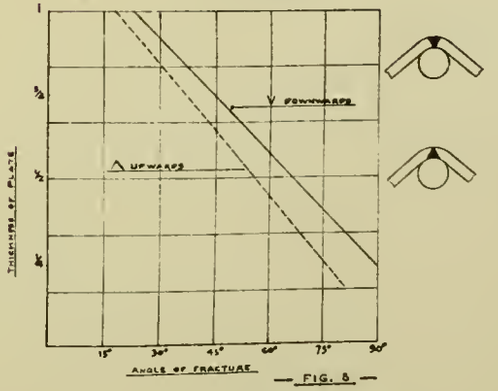


— FIG. 7 A —



— FIG. 7 B —

BENDING TESTS.



— FIG. 8 —

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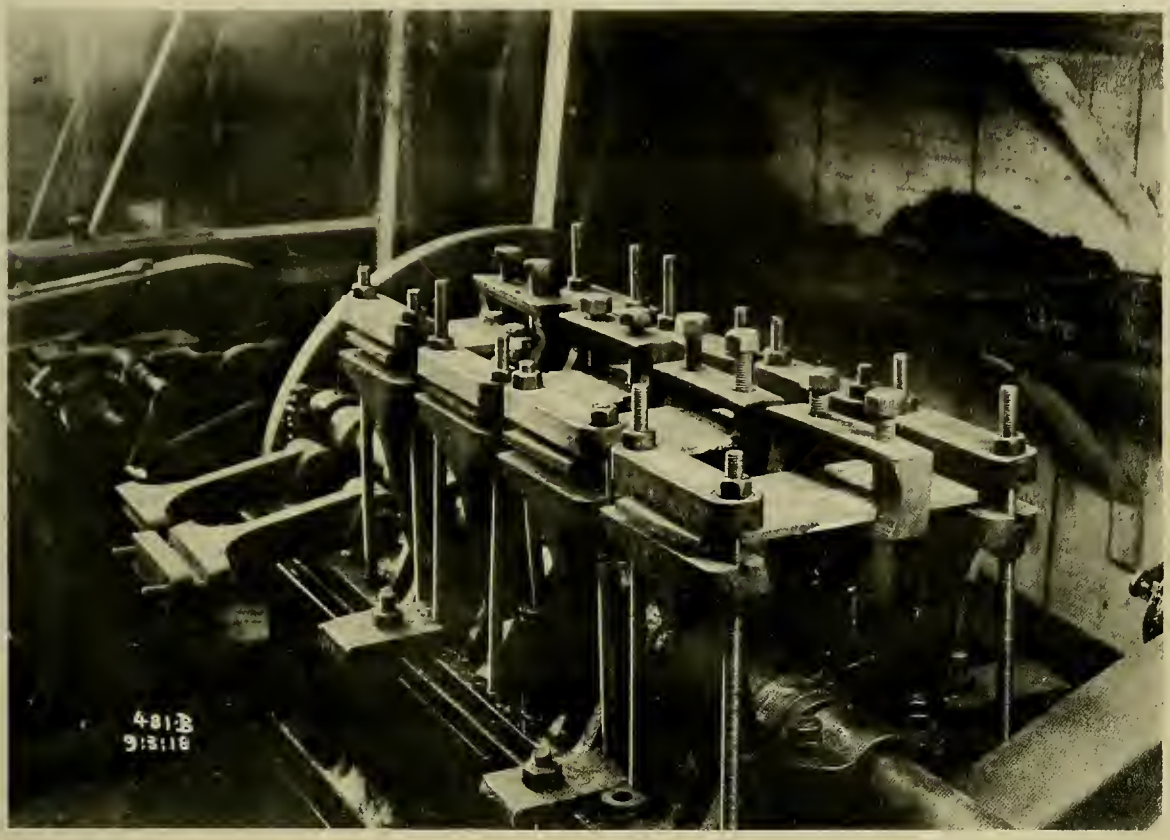

Fig. 1.—Lloyd's Register Experiments. Machine Used for Stationary Alternating Stress Tests.

Fig. 2.—Electric Welded Barge, Built at Richborough, England.

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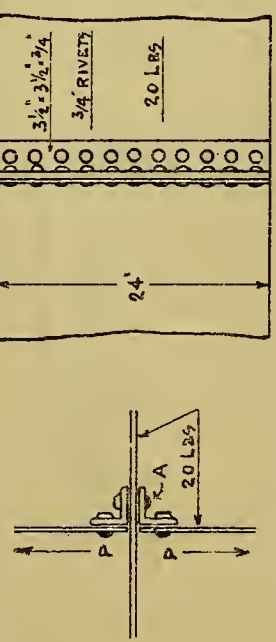
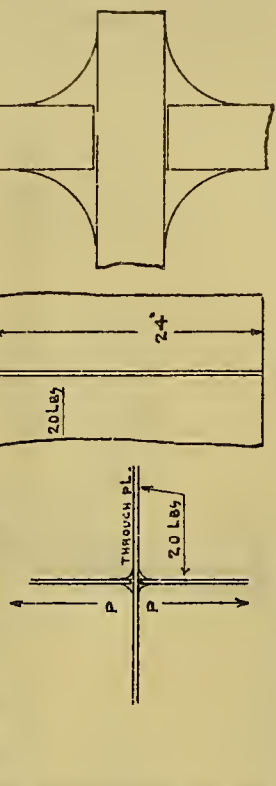
TESTS TO DETERMINE RELATIVE VALUE OF CAULKING AND WELDING.

RIVETED TEST PIECE.



LOAD APPLIED TONS	REMARKS
5·0	NO APPARENT MOVEMENT
10·0	" " "
15·0	CAULKING OPENED ONE SIDE $\frac{35}{1000}$" OTHER SIDE $\frac{5}{1000}$"
20·0	" " " " ⅛" " " ⅛"
30·0	" " " " 3/16"
40·0	" " " " 7/16"
49·0	RIVET POINTS PULLED THROUGH ANGLE AT "A"

WELDED TEST PIECE.



LOAD APPLIED TONS	REMARKS
50·0	NO MOVEMENT
100·0	" "
125·0	" "
150·0	" "
170·0	" "
209·0	BROKE THROUGH PLATE AT HOLDER
LIMIT OF MACH.	WELDING INTACT.

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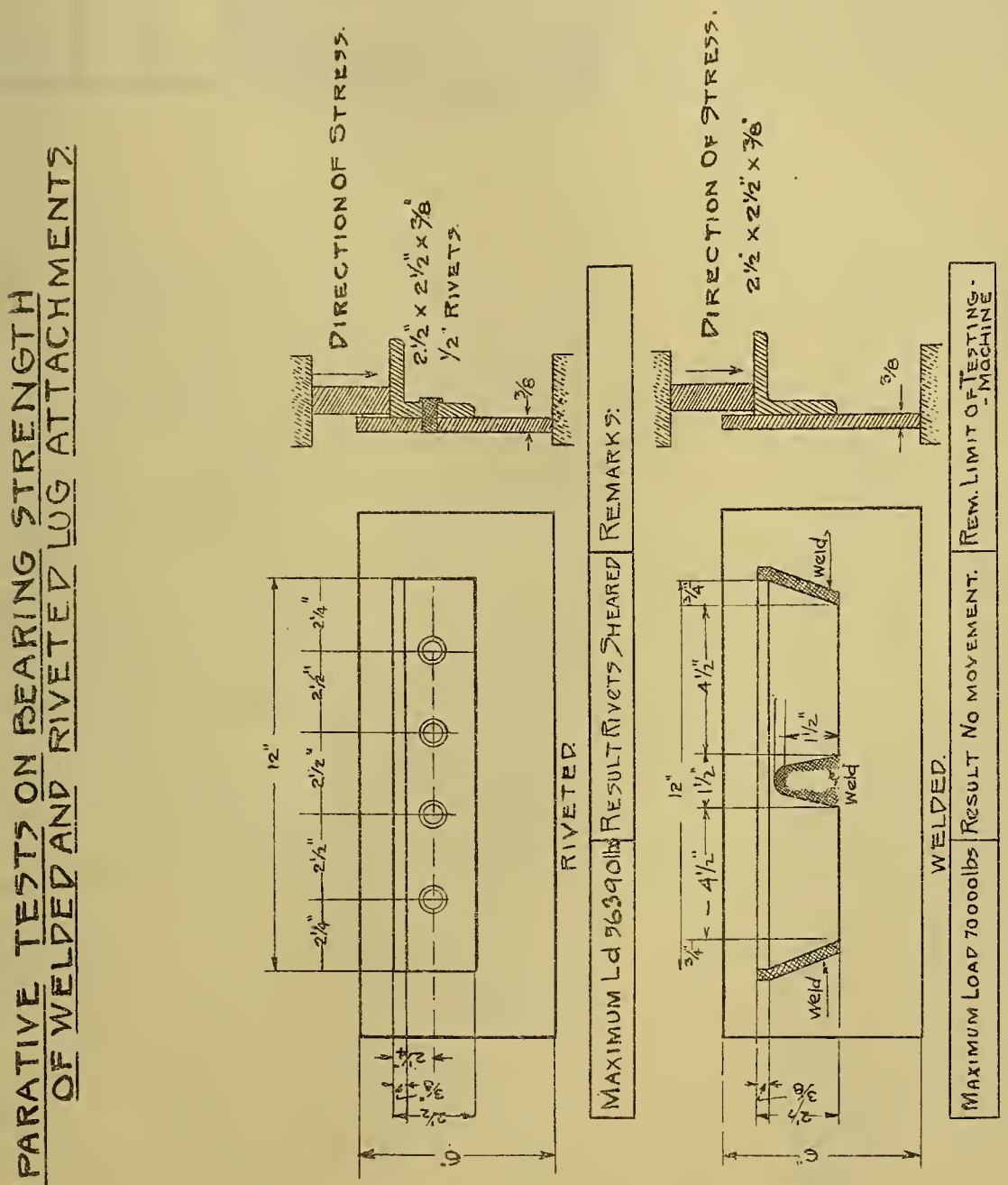

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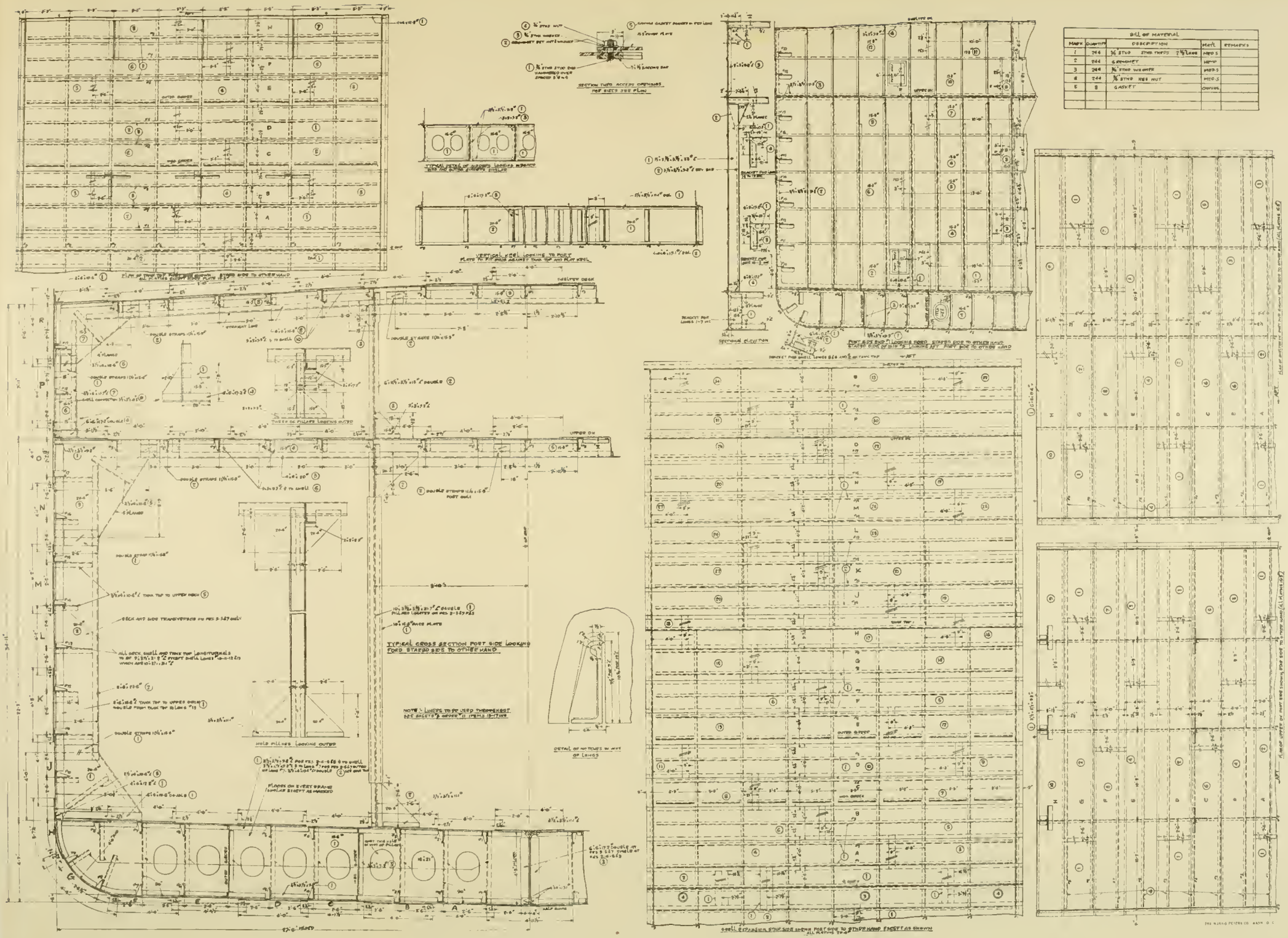
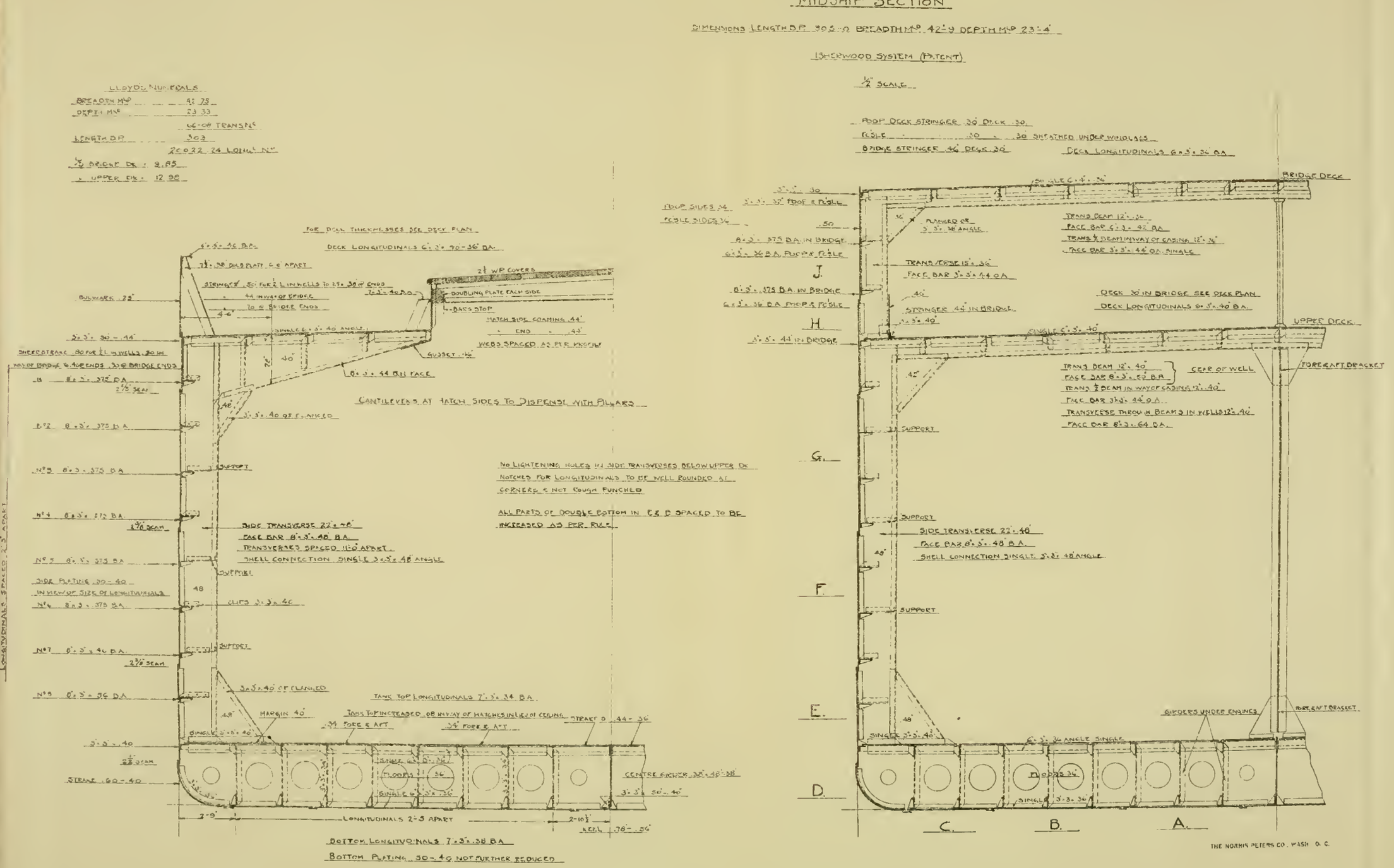

BILL OF MATERIAL
MARK
QUANTITY
DESCRIPTION
MAT'L
REMARKS
1 244 ⅝ STUD STUD THRDS 7⅝ LONG MED S
2 244 GROMMET HEMP
3 244 ⅝ STUD WASHER MED S
4 244 ⅝ STUD HEX NUT MED S
5 8 GASKET CANVAS
SECTION THRU ACCESS OPENINGS
VERTICAL KEEL LOOKING TO PORT
SECTIONAL ELEVATION
TYPICAL CROSS SECTION PORT SIDE LOOKING FORD STARBD SIDE TO OTHER HAND
HOLD PILLARS LOOKING OUTBD
DETAIL OF NOTCHES IN WAY OF LONGS
SHELL EXPANSION STBD SIDE SHOWN PORT SIDE TO STBD HAND EXCEPT AS SHOWN

To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



THE NORRIS PETERS CO., WASH. D. C.

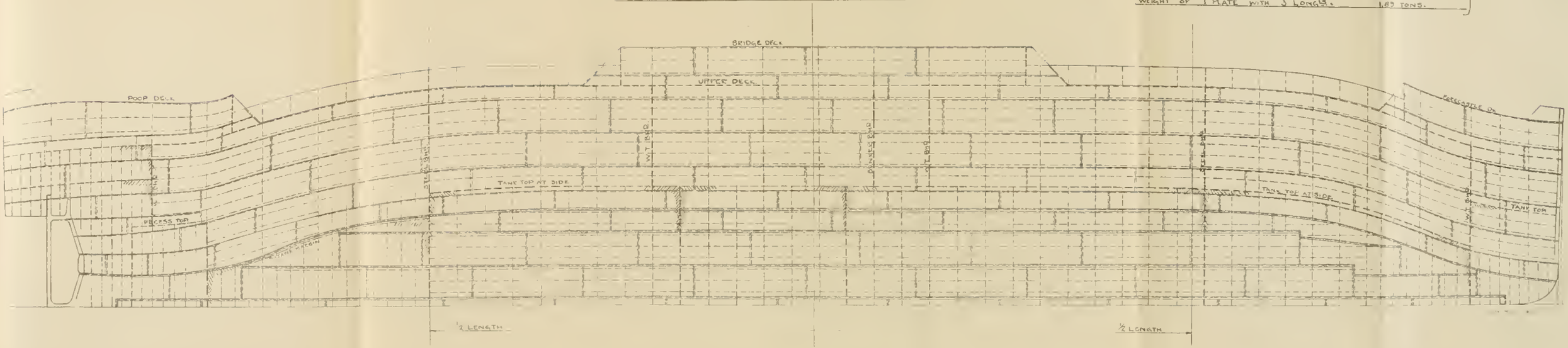
To illustrate paper on The Application of Welding to Ship Construction
by H. Jasper Cox, Esq. Member

SHELL EXPANSION

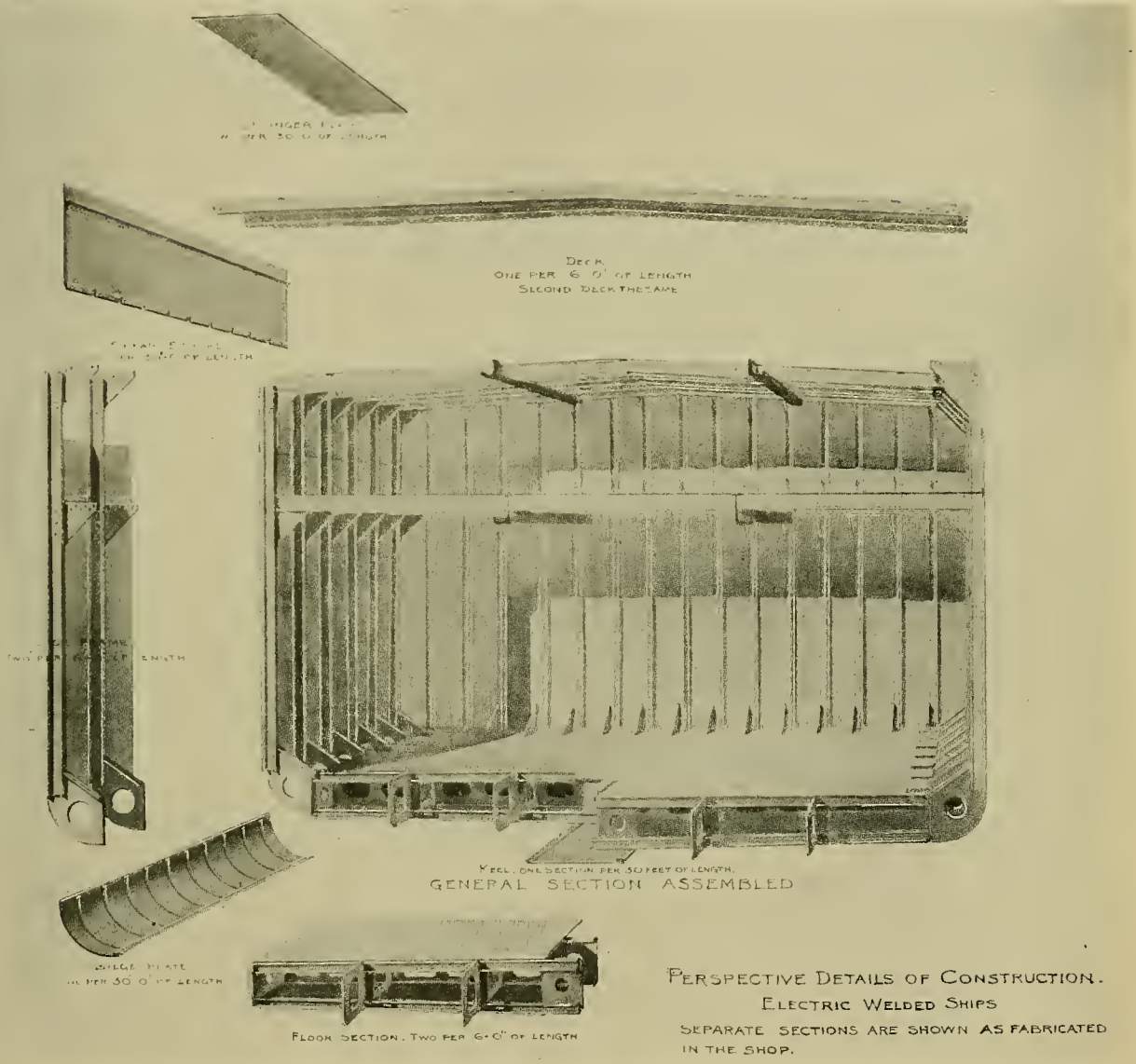
SCALE ⅛ INCH - 1 FT

TOTAL PLATES EACH SIDE INCLUDING KEEL = 147 PLATES
" - FOR ½ L EACH SIDE " " = 72 "

WELDING	APPROXIMATE	
LIGHT WELDING IN SEAMS	6892 FT BOTH SIDES	TOTAL 13798 FEET
FULL " " "	4852 " " "	
FULL " " BUTTS	1310 " " "	
BUTTS OF LONGS FULL WELDING	382 " " "	
" " " LIGHT "	362 " "	
WEIGHT OF 1 PLATE WITH 3 LONGS.	1.83 TONS.	



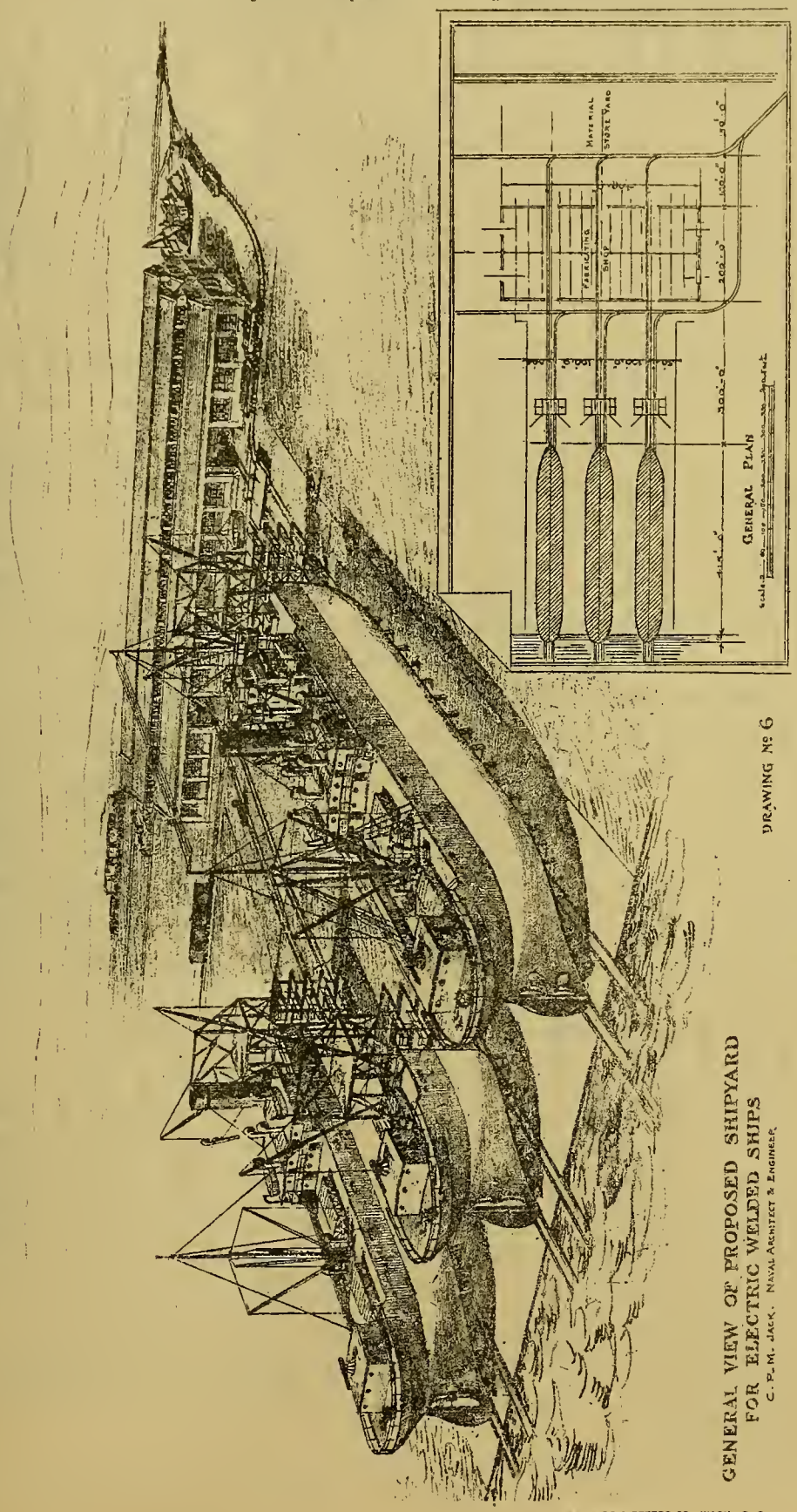
To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



PERSPECTIVE DETAILS OF CONSTRUCTION.
ELECTRIC WELDED SHIPS
SEPARATE SECTIONS ARE SHOWN AS FABRICATED IN THE SHOP.

TRANSVERSELY PLATED VESSEL.

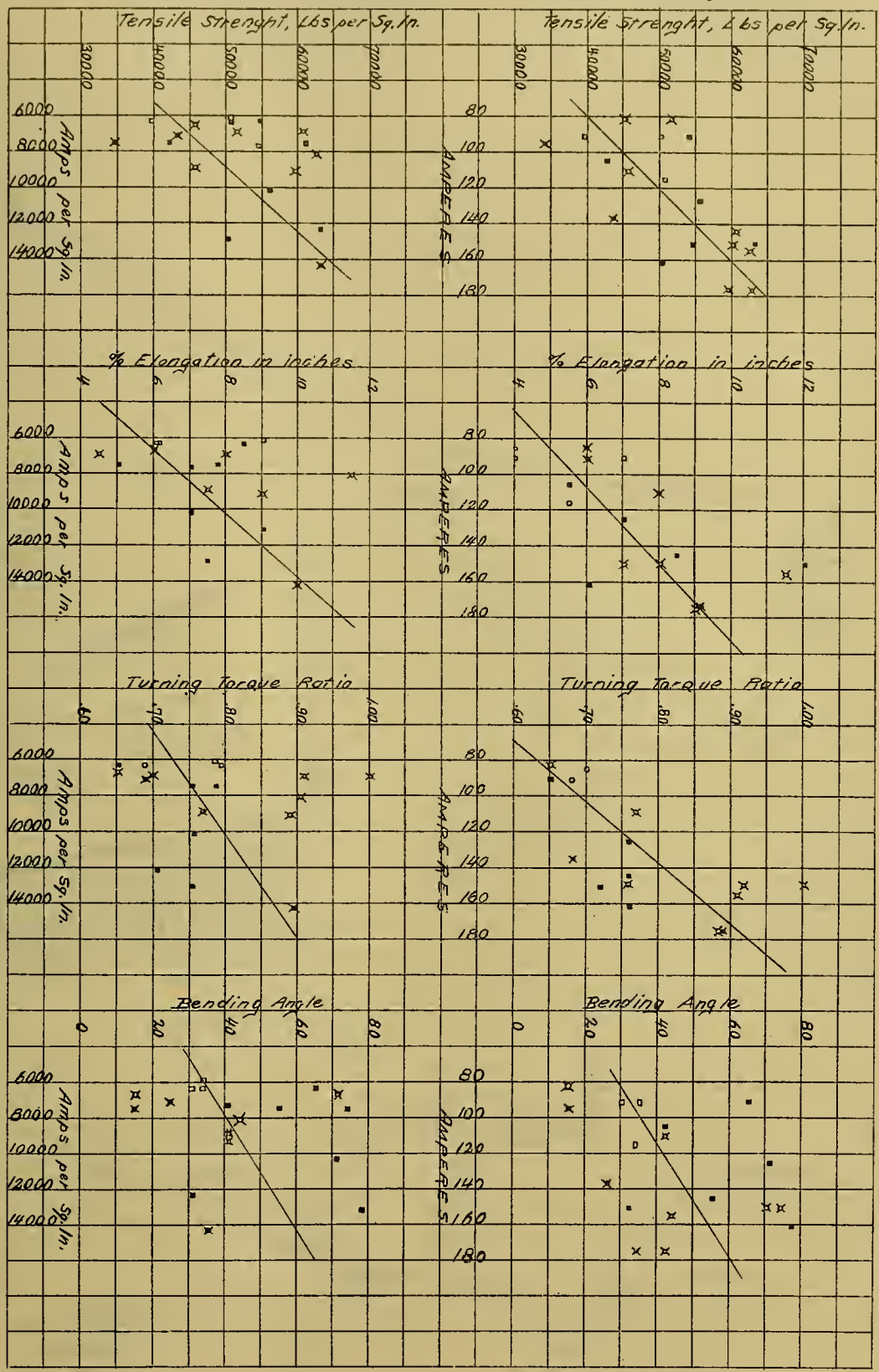
To illustrate paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



Transversely Plated Vessel Method of Construction

THE NORRIS PETERS CO., WASH., D. C.

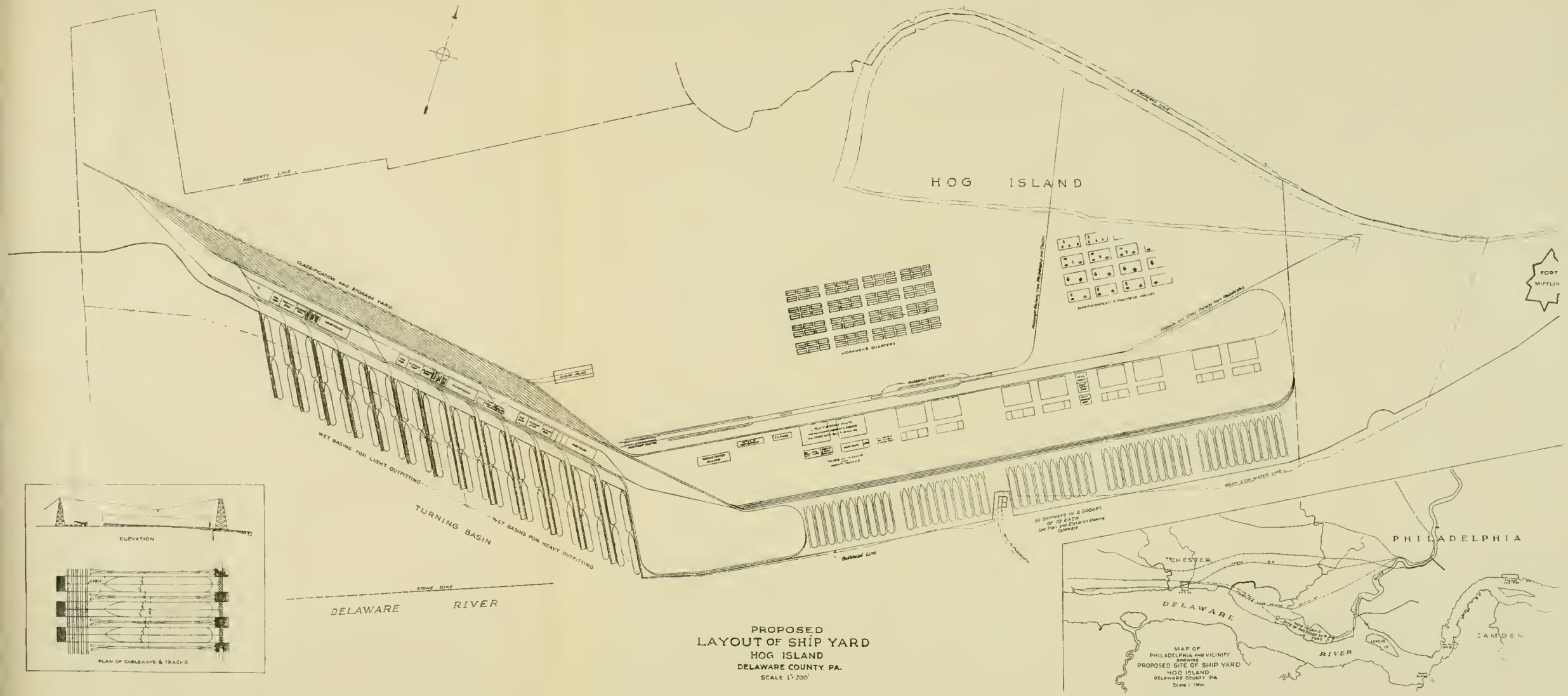
To illustrate discussion by H. M. Hobart, Esq., Visitor, on paper on "The Application of Electric Welding to Ship Construction," by H. Jasper Cox, Esq., Member.



GENERAL ELECTRIC COMPANY, SCHENECTADY, N.Y. U.S.A. (METRIC DIVISIONS)

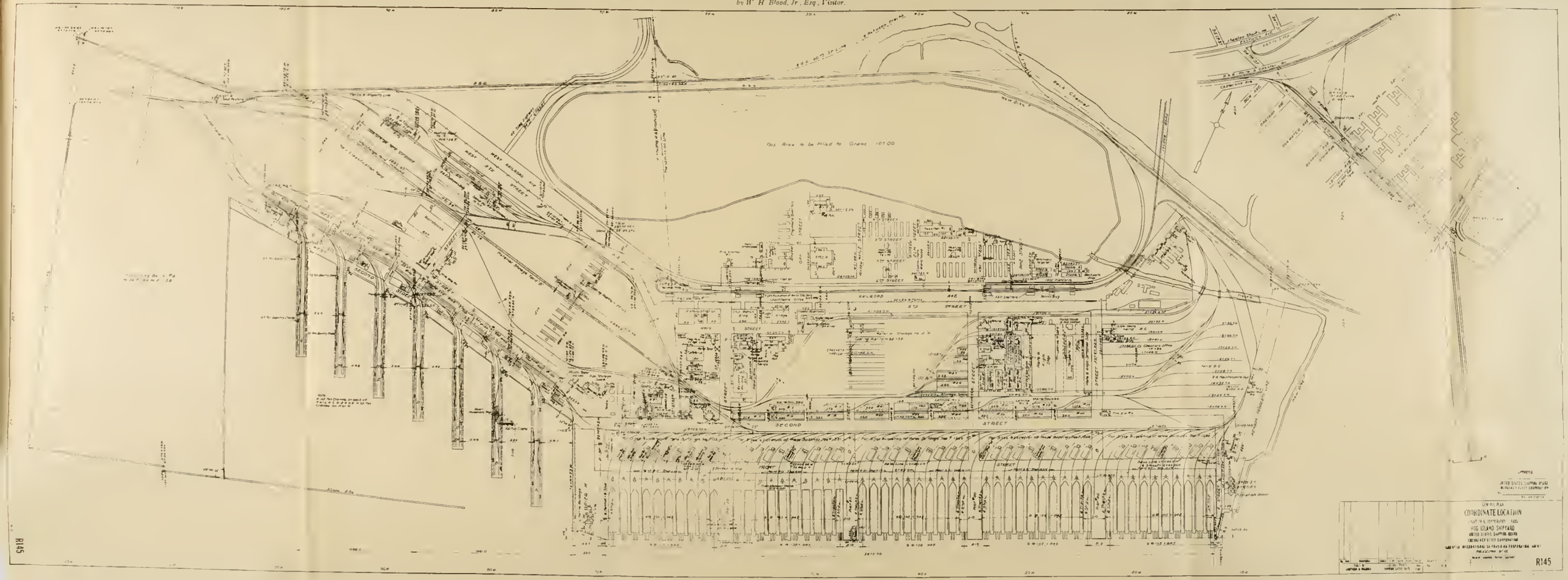
THE NORRIS PETERS CO., WASH., D. C.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World." by W. H. Blood, Jr., Esq., Visitor.



PROPOSED
LAYOUT OF SHIP YARD
HOG ISLAND
DELAWARE COUNTY, PA.
SCALE 1" = 200'

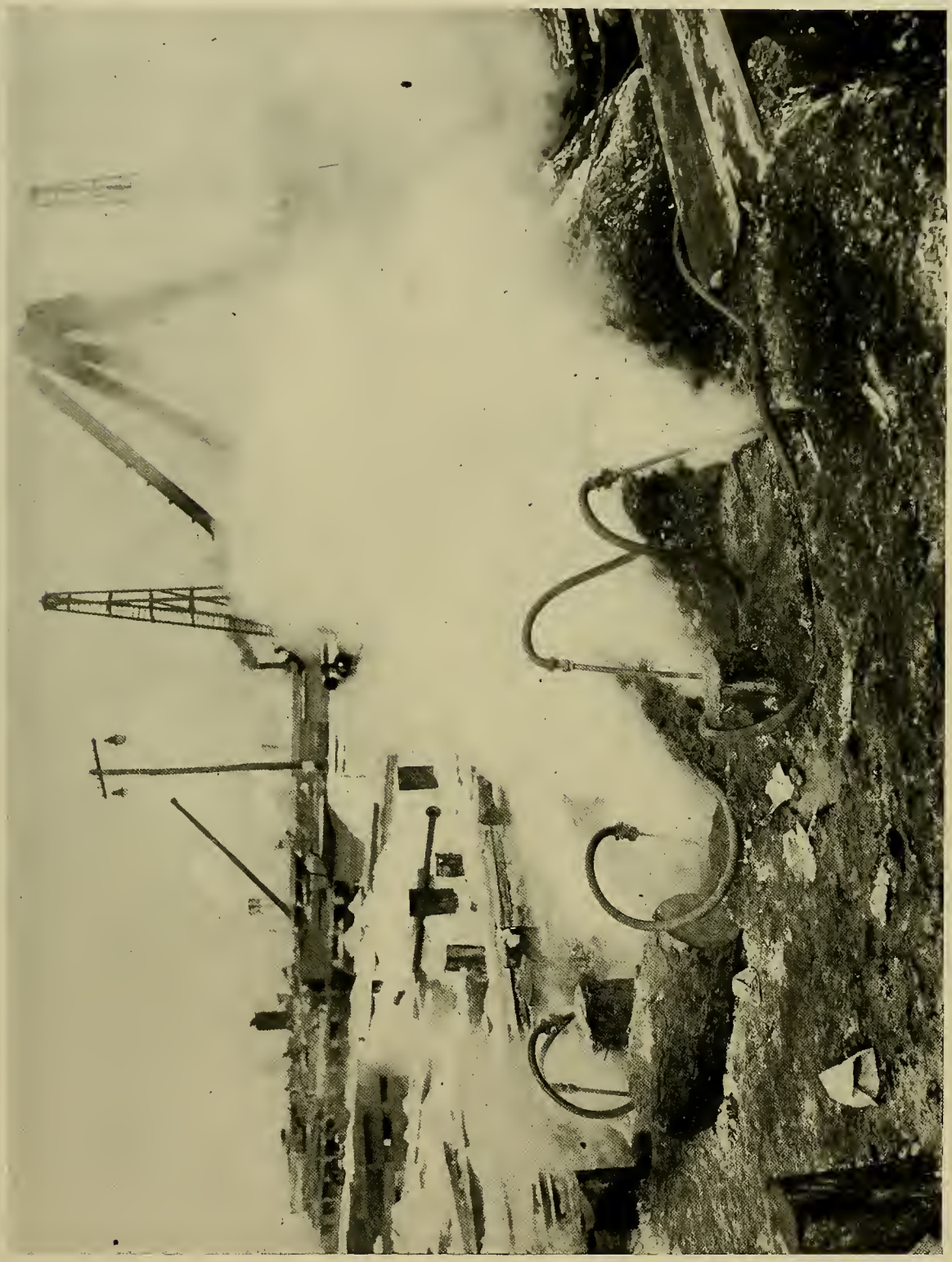
To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.



To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.

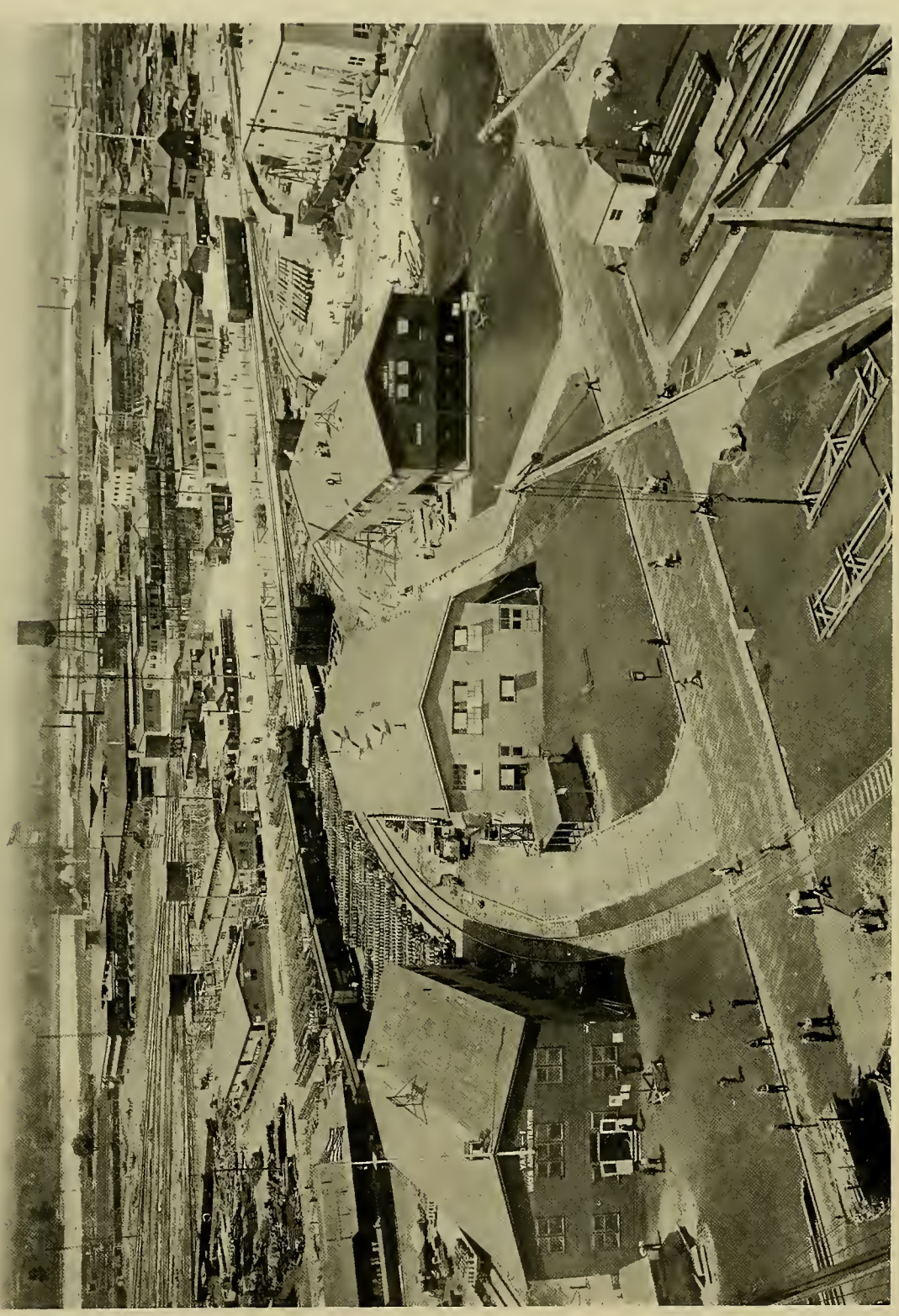
Shore Line Upstream from Top of Pile Driver, Ferry House in Distance.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.



Thawing Ground with Live Steam Before Excavating.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.

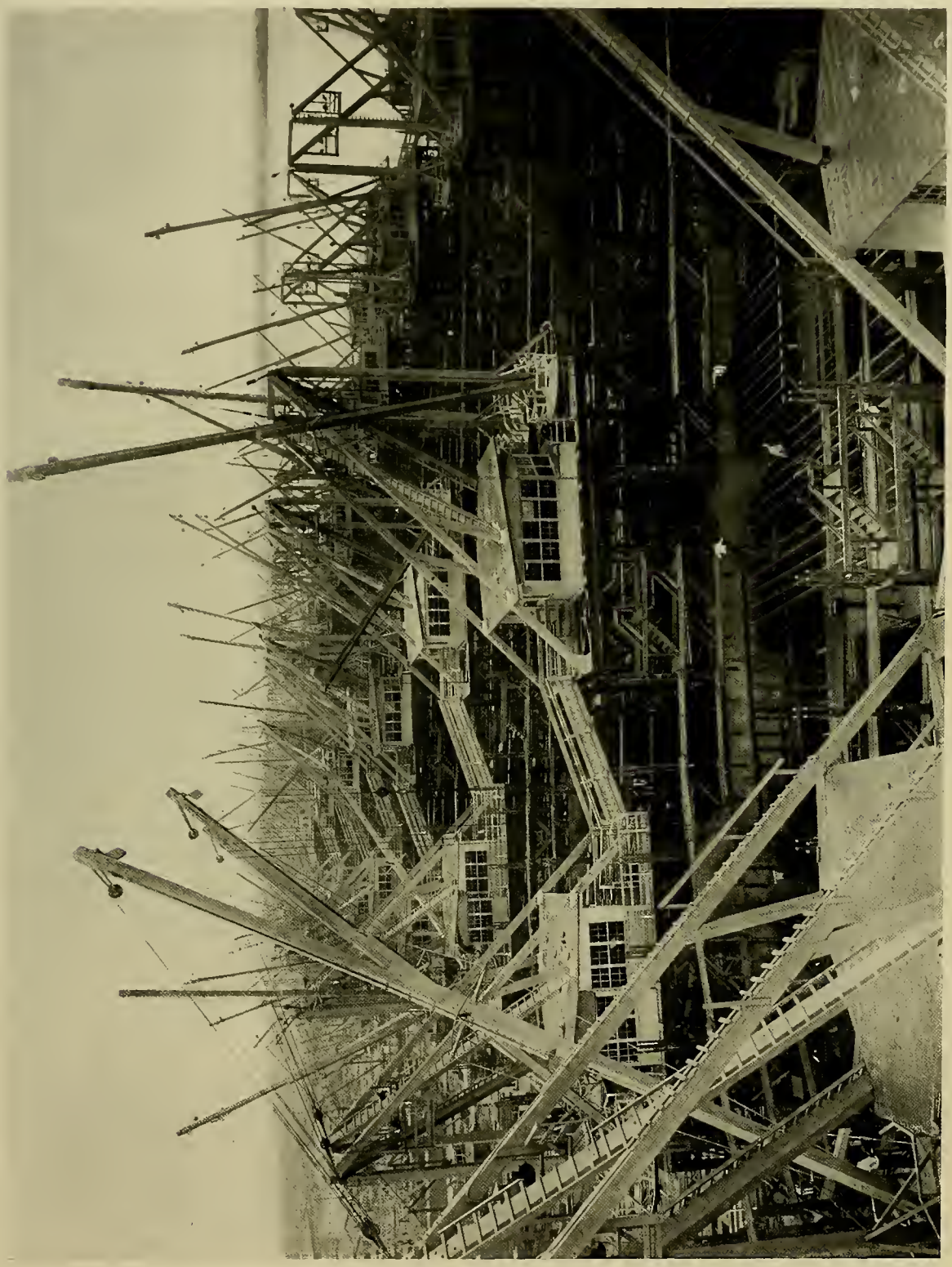


General View North from Way No. 1.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.

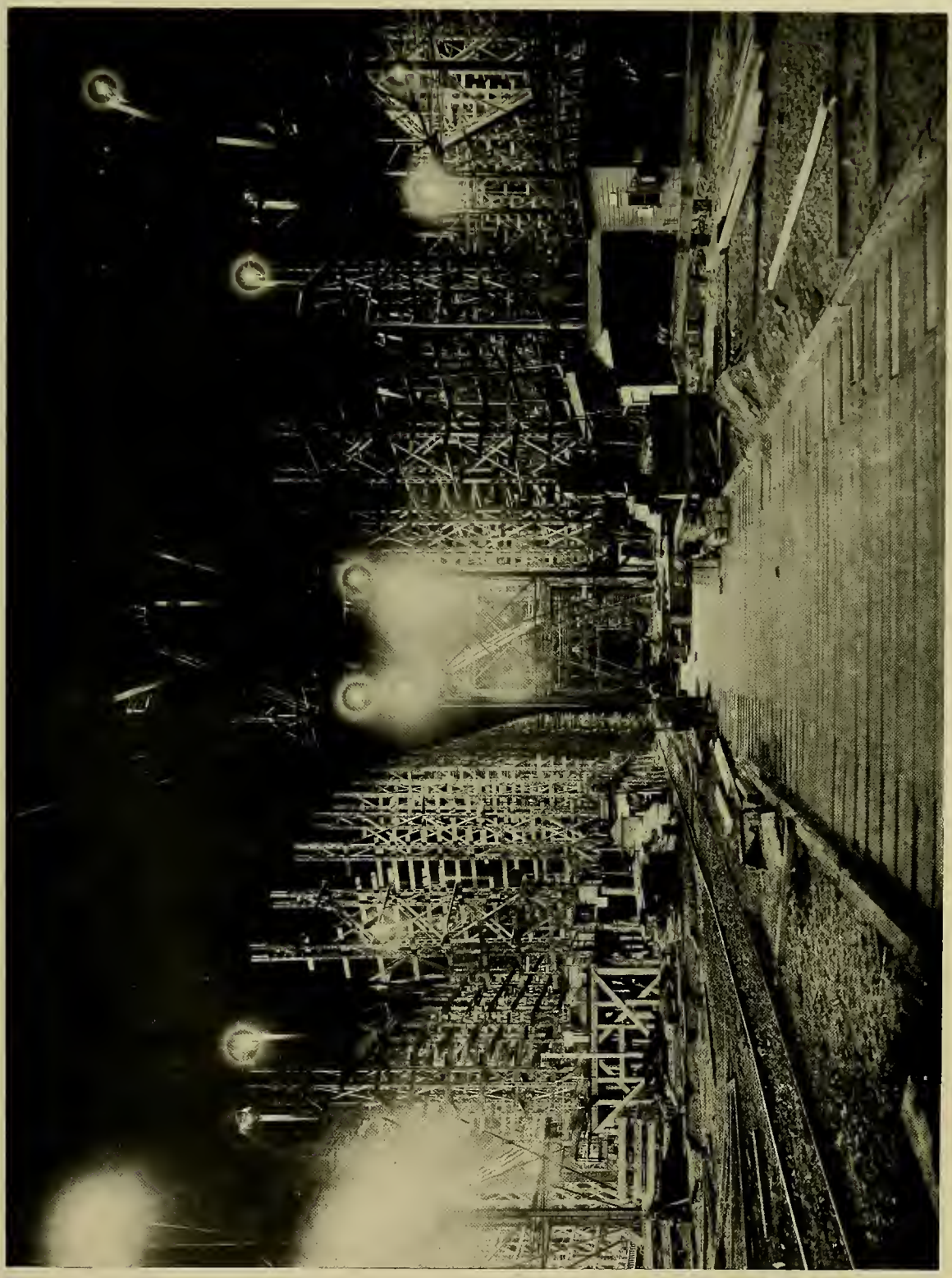
Group No. 1. Shipways Nos. 1, 2, and 3.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.



Looking East from Way No. 1, Showing Forest of Derrick Masts.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.

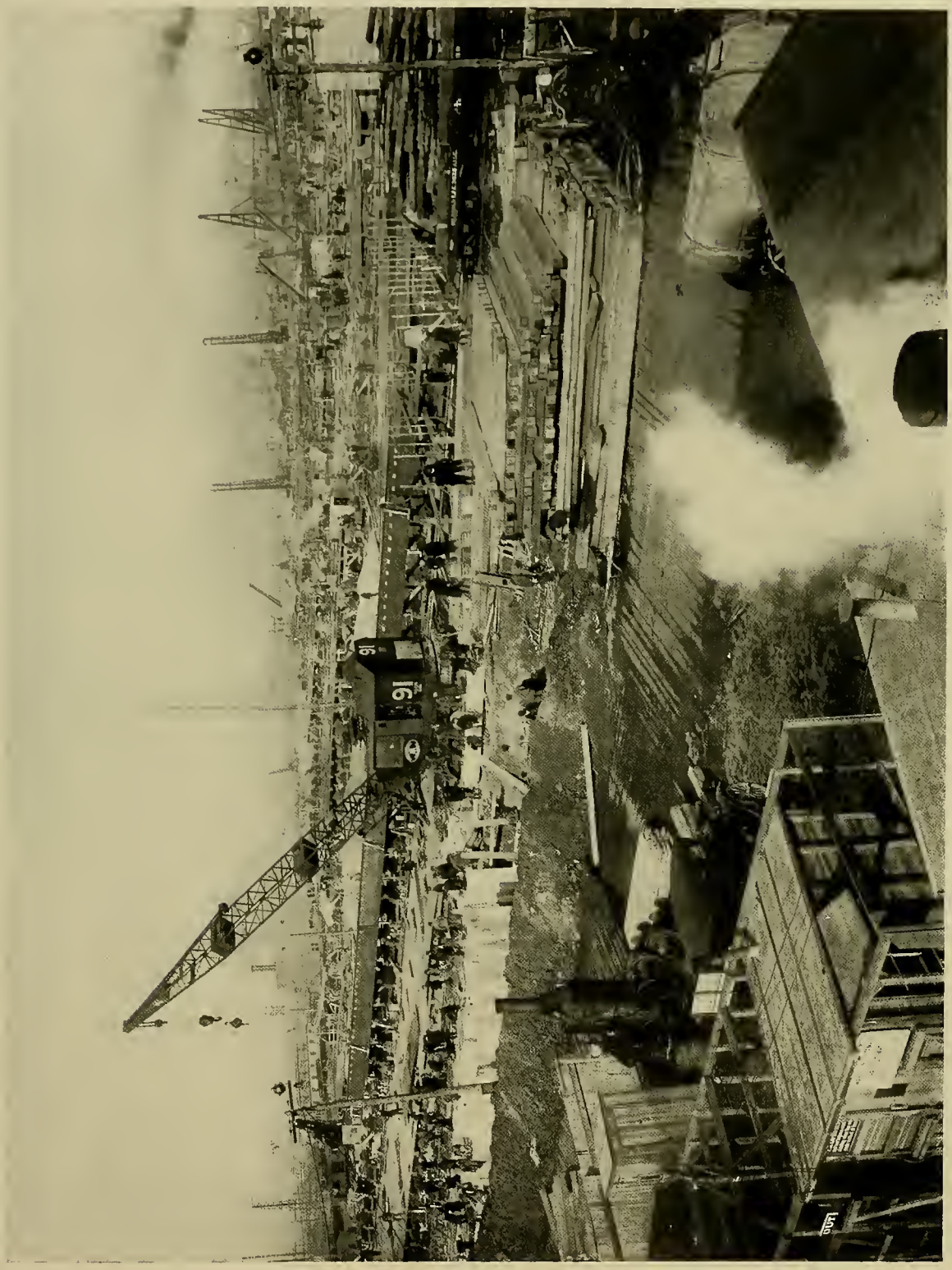


Typical Night Lighting of Shipways, Group No. 1, 11 P. M.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.

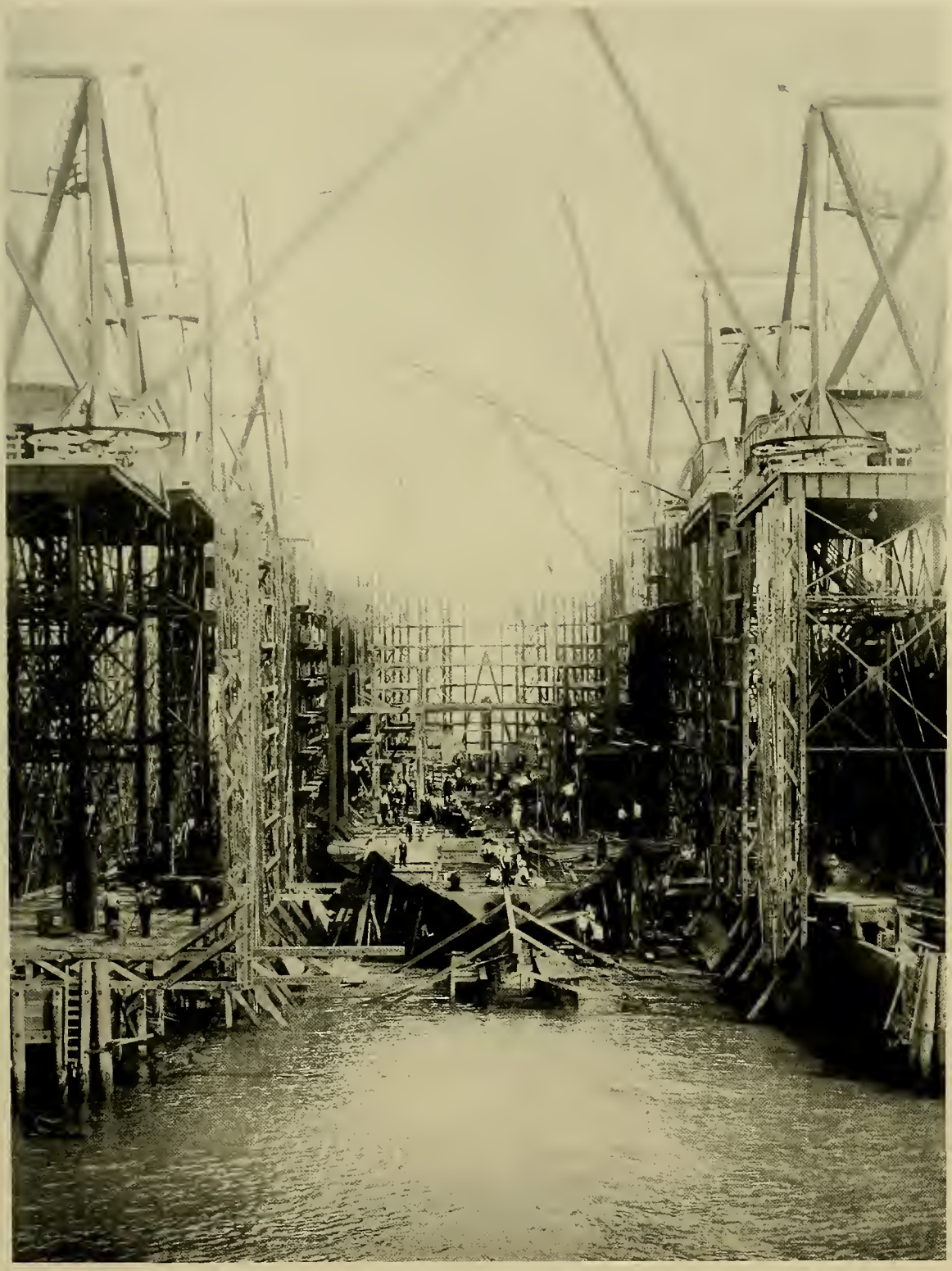
General View Northeast from Way No. 1.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.



Laying First Keel, Way No. 1, Group No. 1, Northwest from Main Wharf.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.

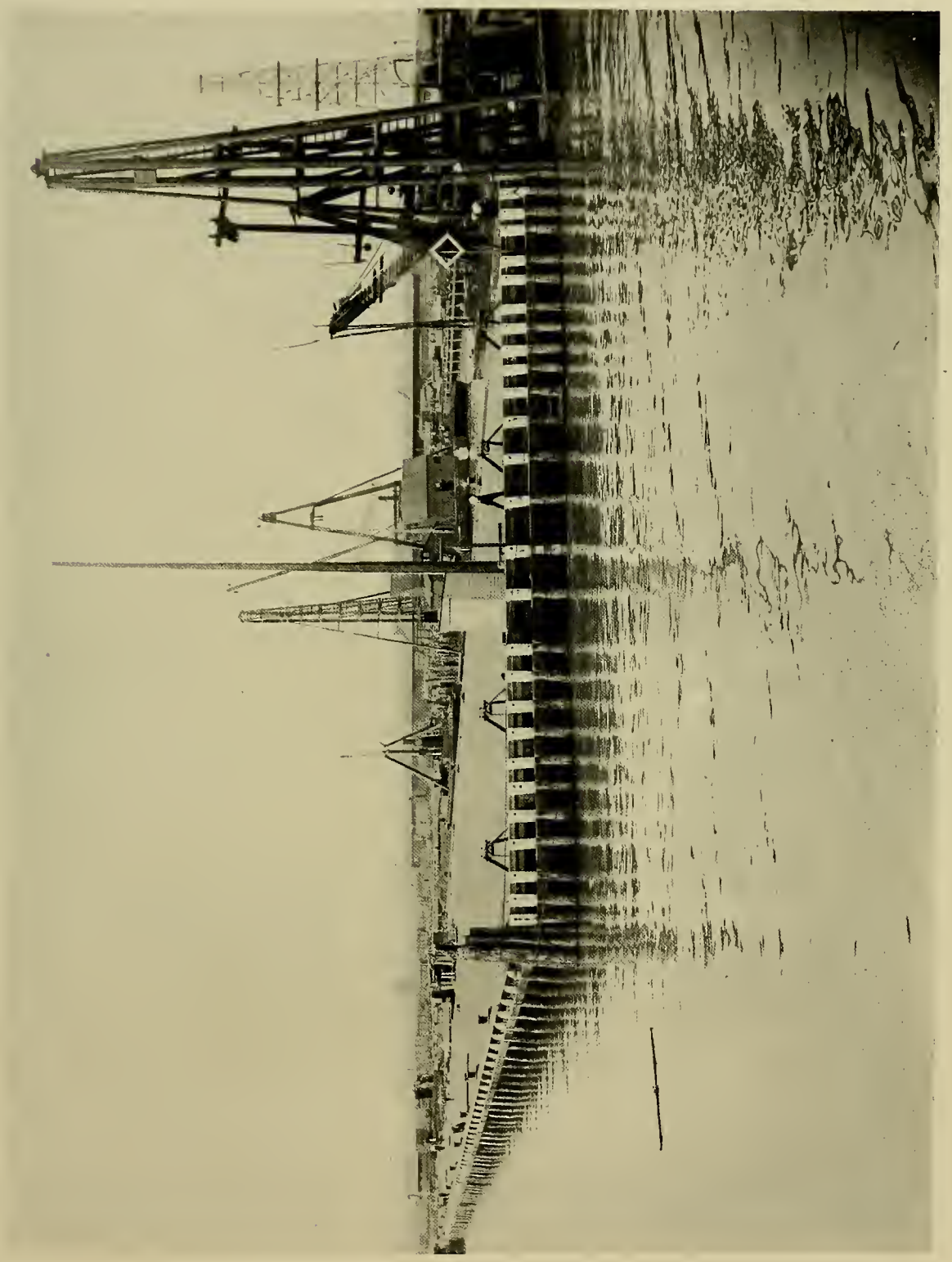


Way No. 19. Hull No. 507.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.

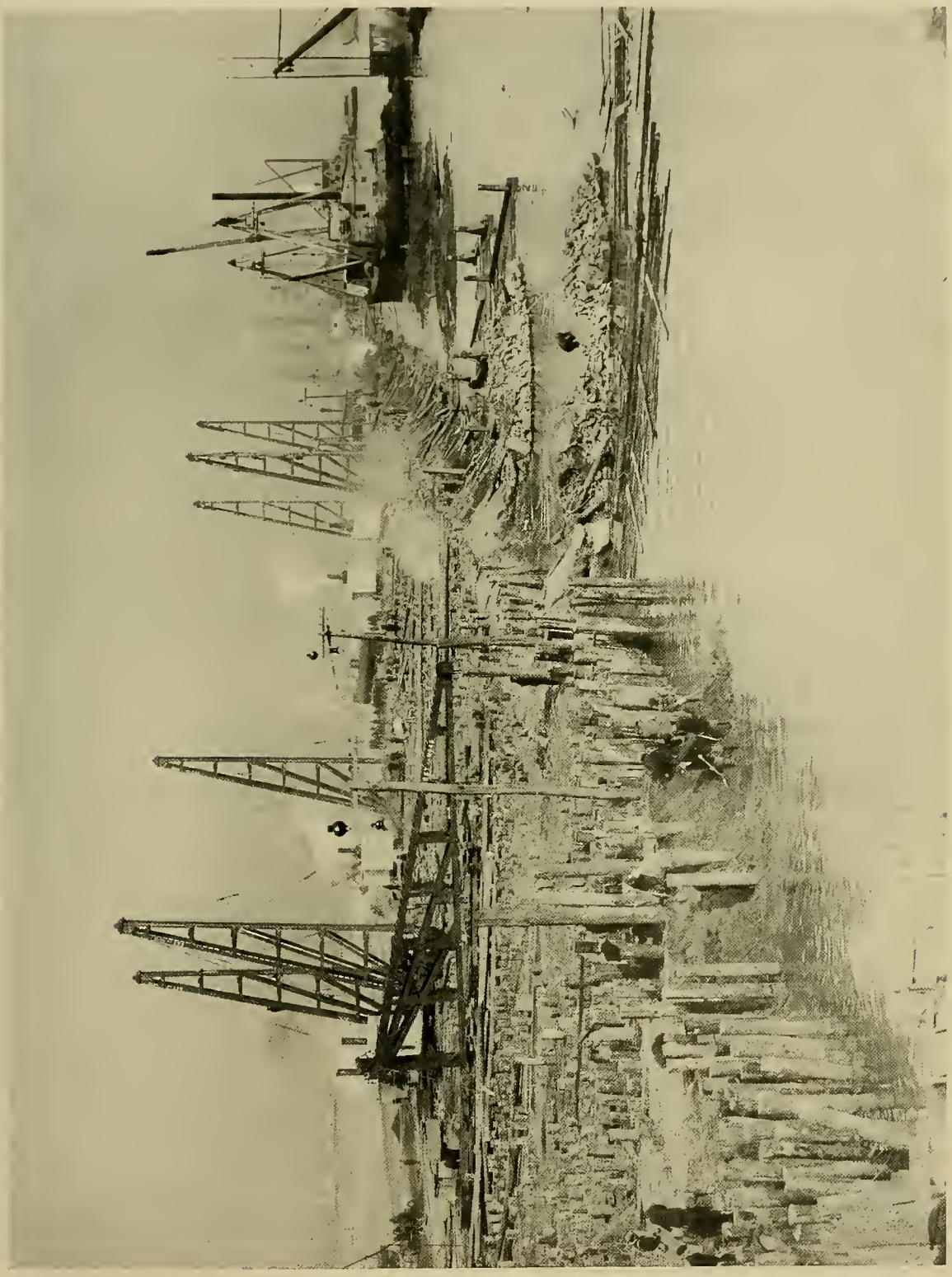
View Northwest to Extreare Shore Bound.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.



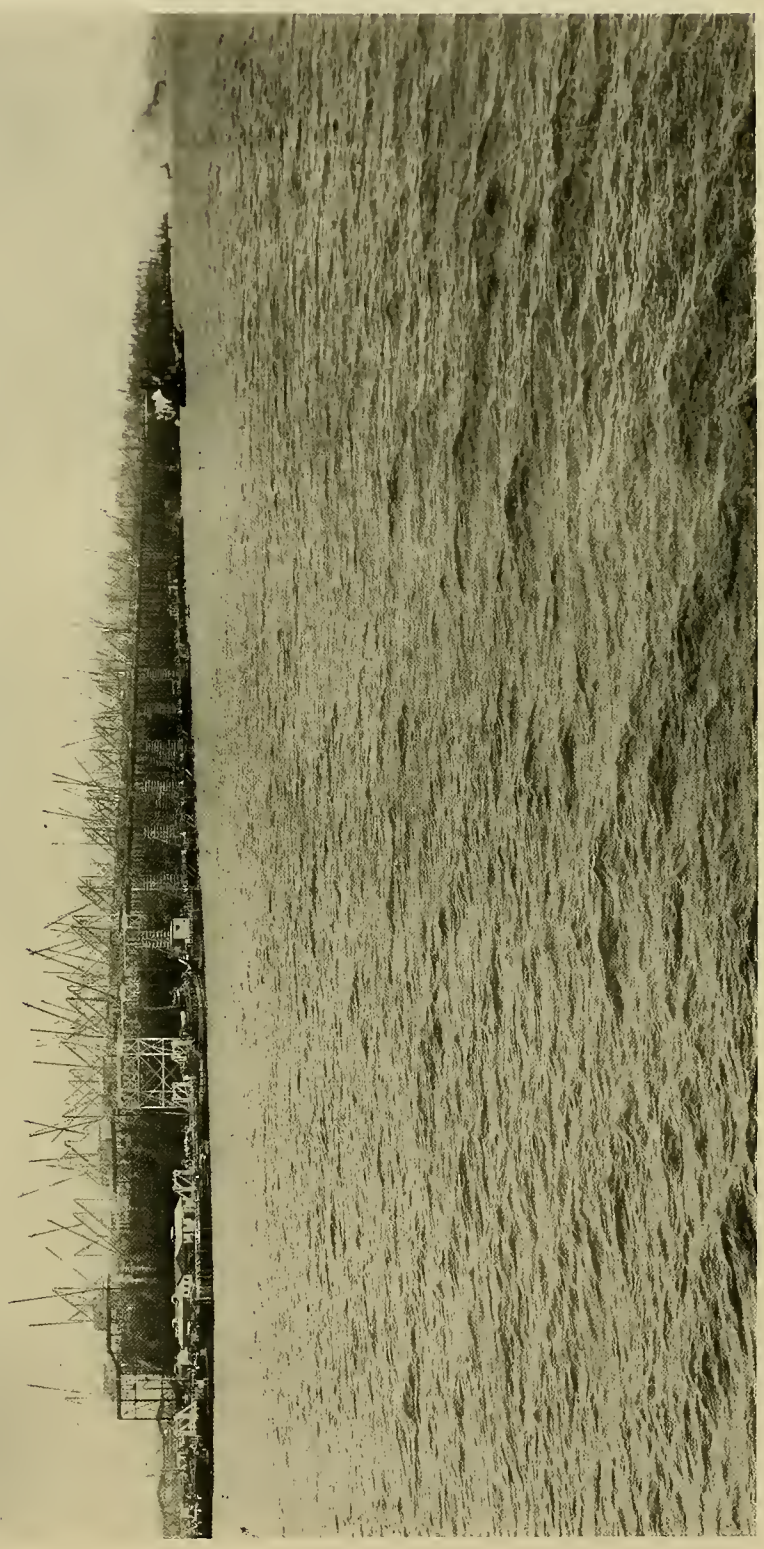
Pier B.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.



East from Main Wharf.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.

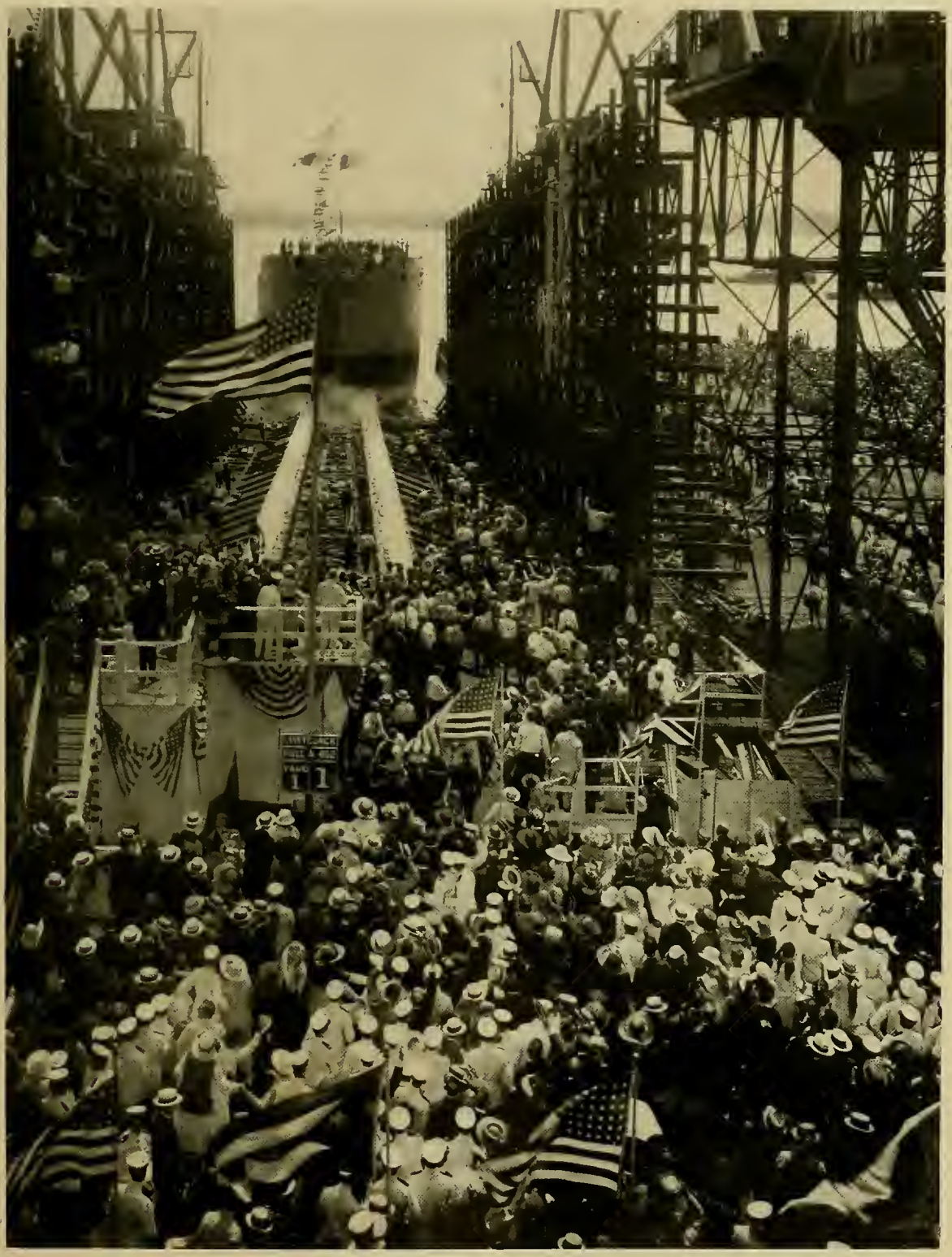


General River View of Shipways Northeast from Main Wharf.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.

WORKMEN GATHERED AT ADMINISTRATION BUILDING TO HEAR SPEECHES BY DR. EATON AND CORPORAL STREET.

To illustrate paper on "Hog Island, the Greatest Shipyard in the World," by W. H. Blood, Jr., Esq., Visitor.



QUISTCONCK LAUNCHING. SLIDING INTO THE DELAWARE.

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